Illinois Grower's Guide to

# Superior Soybean Production


University of Illinois at Urbana-Champaign
College of Agriculture, Cooperative Extension Service
Circular 1200

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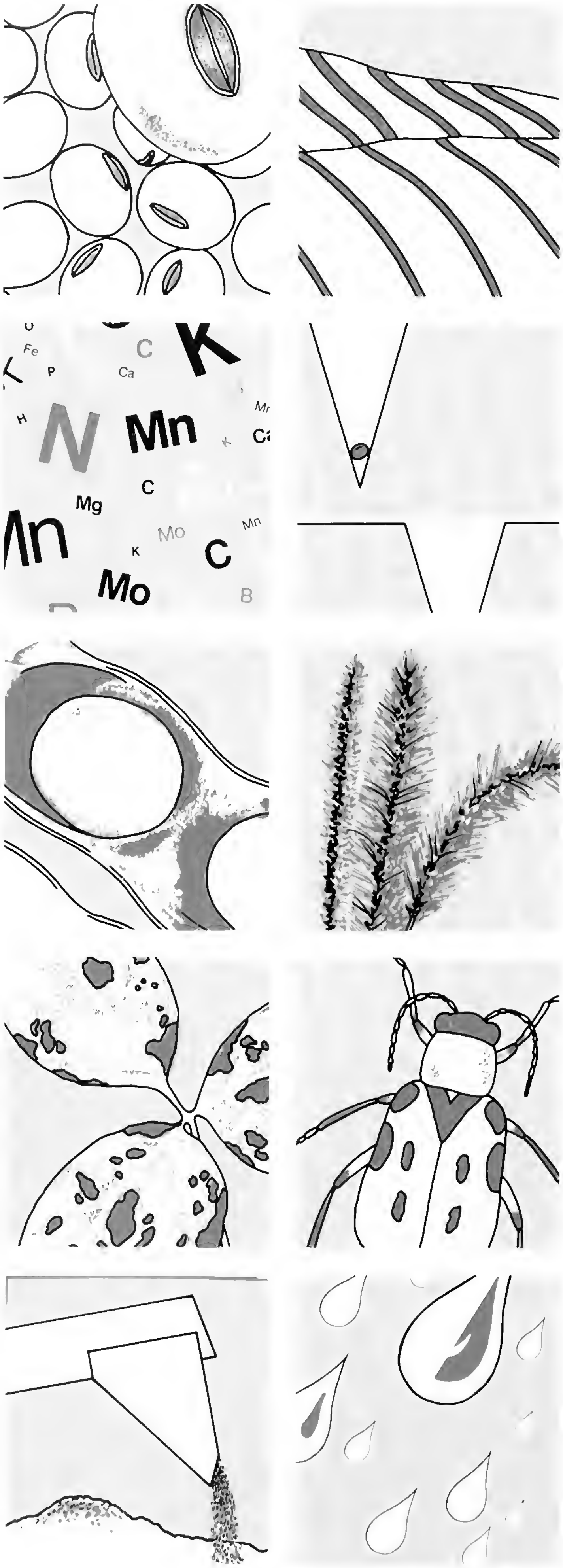



# Contents

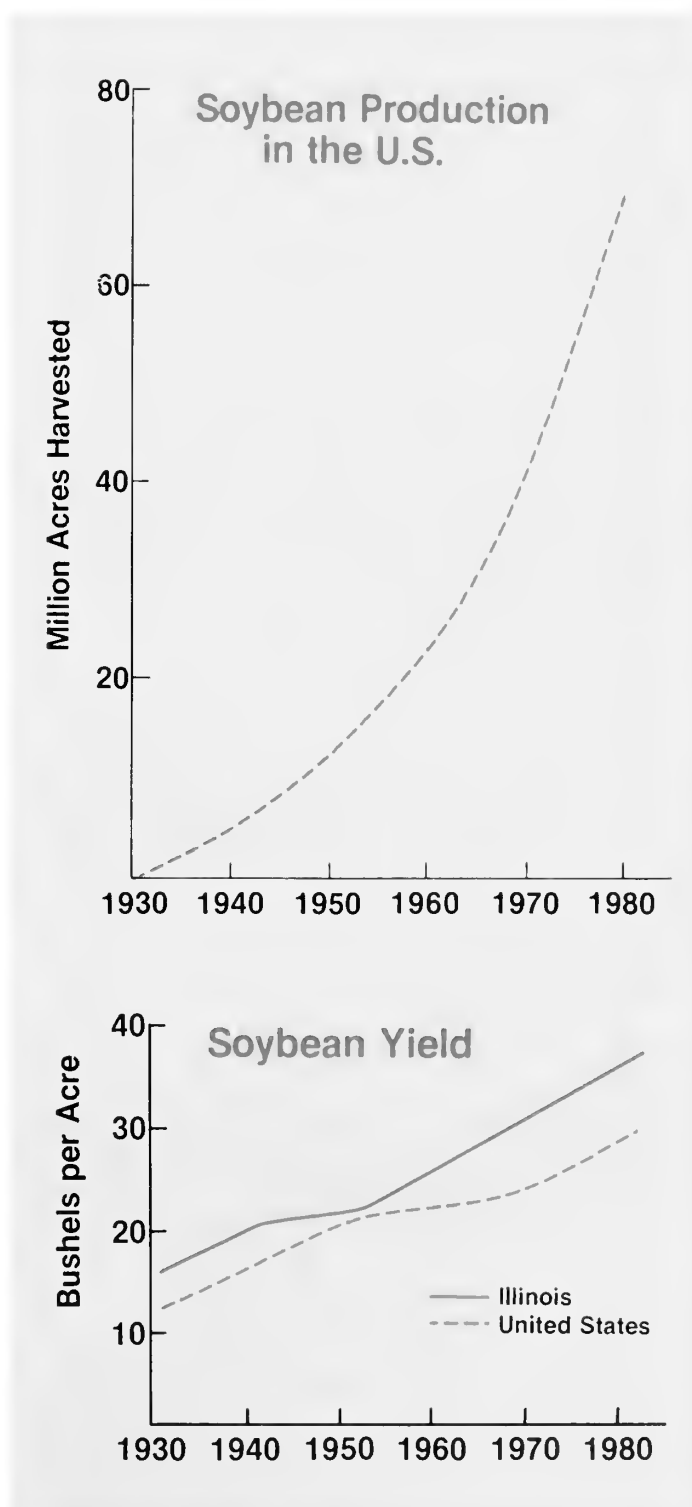
# Preface

The soybean is probably native to eastern Asia. The people of that region have grown soybeans and used them in a variety of foods for hundreds of years. In the last 30 years, soybeans have become an important crop in the United States.

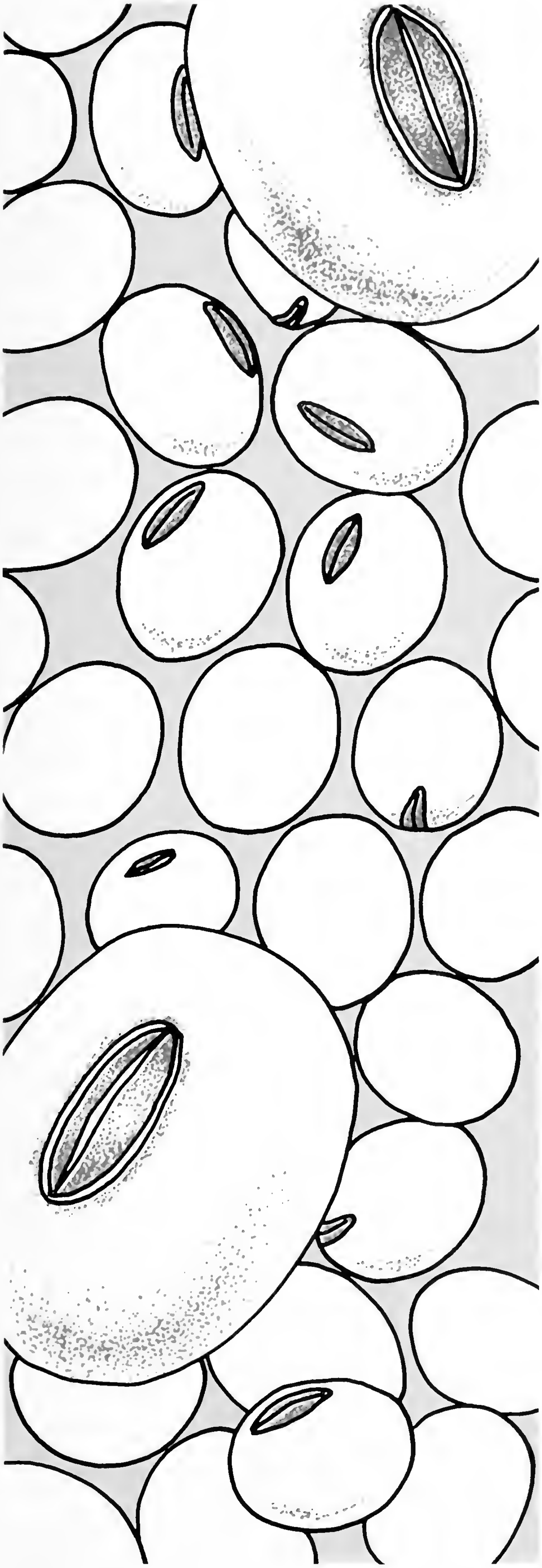
Illinois farmers first began to cultivate soybeans around 1900. In 1919, 15,000 acres of soybeans were produced in the state. Only 3,000 acres were grown for seed harvest; most were grown for hay or soil improvement. Since that time, there has been a fairly steady trend toward cultivation of soybeans for seed harvest. By the mid-1930s about half of the soybeans planted in the state were grown for seed harvest and the rest for forage. Soybeans are currently grown for seed harvest on around 9.5 million acres in Illinois, and almost no soybeans are grown for forage. In the United States, soybean acreage is now roughly 70 million.

This increase in the number of acres used for soybean production has been paralleled by a dramatic increase in soybean yields both in Illinois and the United States (see the accompanying graphs). At one time, yields of 10 to 15 bushels per acre were common. Now, because of improved varieties and better cultural practices, it is not uncommon for yield tests to produce 50 to 60 bushels per acre.

The purpose of this publication is to provide information on every phase of soybean production. It deals with soybean varieties, tillage systems, soil fertility, planting, seed quality, pest control, harvesting, and moisture management. This information is intended to help soybean producers make better decisions and maintain the trend toward increased yields and profits. Specific recommendations about such matters as chemical control are available in other publications distributed by the College of Agriculture, University of Illinois at Urbana-Champaign. These resources are referred to throughout this publication and are listed on page 68.




During the last 50 years, soybean production has increased sharply in the United States, top. This increase has been paralleled by an equally dramatic rise in soybean yield both in the United States and Illinois, bottom.



# Selecting a Variety

Selecting the most appropriate variety is essential to profitable soybean production. The choice can be difficult because so many varieties are available. The pace at which private companies, the U.S. Department of Agriculture, and agricultural experiment stations develop new varieties has increased rapidly in recent years, and it appears that many more varieties will be developed in the future. Many blends are also being marketed. Blends are mixtures of two or more varieties; they are labeled "soybean varieties not stated" and are identified by brand name. Neither Illinois nor federal seed laws require that blends be reconstituted with the same varieties in the same proportion from year to year.

When choosing a soybean variety, study carefully information published by the Illinois Agricultural Experiment Station and the results of commercial variety tests. These tests are conducted at several locations in Illinois each year, and the results are published by the Cooperative Extension Service. Ask your county Extension adviser for the current edition of *Performance of Commerical Soybeans in Illinois.* Choose the variety, blend, or brand that gives the highest yield, and consider carefully its maturity group, growth type, and resistance to lodging and diseases.

## Maturity

Soybean varieties can be classified according to the amount of time it takes them to mature. How quickly they mature depends upon their sensitivity to photoperiod, that is, to the length of continuous darkness in a 24-hour period. Early maturing varieties require shorter periods of darkness than the later maturing varieties to make the transition from the vegetative to the reproductive stage of growth.

Soybean varieties grown in the United States can be divided into maturity groups that correspond to horizontal bands across the country (see map on page 2). The earliest maturing varieties, which are designated 00, are suited to the northernmost region, and the latest maturing varieties, which are in group VIII, are best adapted to the southernmost region.

The varieties that are best adapted to Illinois are from maturity groups II through V. The ones in group II, such as Corsoy 79 and Century, tend to perform well in northern and central Illinois. Group

III varieties, such as Cumberland, Pella, and Williams 82, are considered full-season varieties in central Illinois and are well suited to southern Illinois. The varieties that are best adapted for southern Illinois, though, are the varieties in group IV, such as Union, Desoto, and Franklin.

## Growth Type

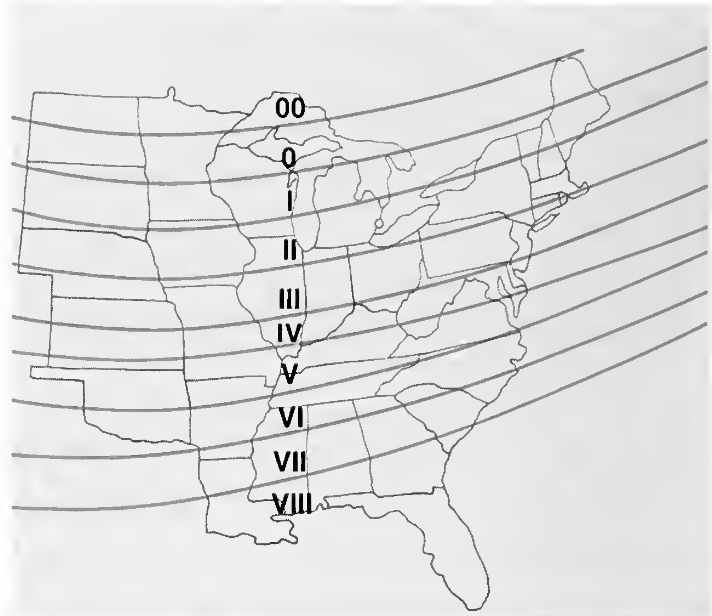
Soyean varieties can be divided into three growth types: indeterminate, semideterminate, and determinate (see photograph at right). Indeterminates grow, flower, and set pods all at the same time. Determinates, in contrast, begin to flower about the time the stem and other vegetative parts of the plants have ceased to grow. The new determinate varieties tend to be much shorter than the indeterminates. Semideterminate varieties, which were released recently, are neither as tall as the indeterminates nor as short as the deteminates. They do not terminate growth of the stem as abruptly as the determinates.

Until 1978, the varieties from maturity group IV and earlier were indeterminate, and the ones from group V and later were determinate. Since that time, determinate varieties have been released that are suited to groups II, III, and IV. These varieties are about half the height of the indeterminates.

The determinates and semideterminates should be planted at high seeding rates and in narrow rows. They grow best in highly fertile soils and in areas where they are not under stress. If they are grown under conditions of stress, low moisture, and low soil fertility, they will not produce as well as indeterminates grown under the same conditions. Further, because stress causes the determinates to be quite short, harvesting is more difficult under these conditions. An additional drawback of the determinates is that they flower for a shorter period than the indeterminates. The determinates are unable to compensate for flower loss resulting from stress during flower production. The chief advantage of the determinates and semideterminates is that they are less prone to lodging.

## Lodging

To reduce losses at harvest, it is essential to choose varieties that are resistant to lodging. Another way you can control lodging is to reduce seeding rates. This measure is necessary if you grow weak-stemmed varieties. When plant populations are too high, the stems will be weak, the internodes will be long, and the plants will be taller and more susceptible to lodging.




The 10 maturity groups corresponding to horizontal bands across the United States. The soybean varieties that are best adapted to Illinois conditions are from groups II through V.

The three soybean growth types, left to right: determinate, semideterminate, and indeterminate.

## Diseases

The severity of diseases in soybeans is influenced by moisture, temperature, and the susceptibility of the variety when pathogens are present. Varieties are available that have resistance to one or more of these diseases: phytophthora root rot, cyst nematode, bacterial pustule, downy mildew, and brown stem rot. For more specific information on disease-resistant varieties, see page 32.

# Tillage Systems

## Types of Tillage Systems

Although many different tillage systems are used in soybeans, most are variations of four basic systems: the moldboard plow, the chisel plow, the disk, and the no-tillage systems. The first is considered the conventional tillage system, and the other three are referred to as conservation tillage systems. The field operations that usually make up these four systems are listed on page 4.

### Moldboard and Chisel Plow Systems

Where a soybean crop is to be preceded by a corn crop, the field is usually disked or chopped before moldboard or chisel plowing in the fall. Disking or chopping may not be necessary if a wide-clearance moldboard plow or a disk- or coulter-chisel plow that will not become plugged with residue is available. If phosphorus and potassium fertilizers or limestone are needed, they are applied either before or after the residue is chopped or disked but before primary tillage.

The number of secondary tillage operations used in the spring depends upon many factors, primarily the roughness of the soil, weed infestation, and your decision whether to incorporate herbicides, if you use them at all. Usually, fields are leveled with a disk or field cultivator as early in the spring as the soil can be worked. Whether this first spring operation is necessary depends on the roughness of the soil surface. If the field was moldboard plowed in the fall, the dead furrows and end rows should be leveled. If the field was chisel plowed, it usually has to be disked in early spring to level the soil surface and to cut and bury more of the corn residue from the previous year.

After the field has been leveled, herbicides are usually applied and incorporated into the soil. Often, they are custom applied, and the farmer then makes the first incorporation pass. Usually, this first pass is made as soon as possible after the herbicides are applied, although the timing varies according to the herbicide. Be sure to follow the recommendation on the herbicide label. A common alternative is to perform these operations simultaneously by applying the herbicides in front of the tillage tool used for the first incorporation pass.

It is usually recommended that herbicides be incorporated with two passes of a disk or field cultivator. Several other tillage tools — powered harrows

| | Moldboard plow | Chisel | Disk | No-Till |
|---|---|---|---|---|
| **Fall** | | | | |
| Disk or chop residue | X | X | X | |
| Moldboard plow .... | X | | | |
| Chisel .............. | | X | | |
| **Spring** | | | | |
| Disk ............... | X | X | | |
| Apply herbicide; disk | X | X | X | |
| Field cultivate ...... | X | X | X | |
| Plant ............... | X | X | X | X |
| Apply herbicide ..... | | | | X |
| Rotary hoe ......... | X | X | X | |
| Cultivate (twice) .... | X | X | X | |

such as the Rottera or combination tools such as the Soil Finisher — are being used to incorporate herbicides in one pass. Although these tools can incorporate herbicides satisfactorily, they do not incorporate the chemicals as deeply as the disk or field cultivator and as a result may not control deep-seeded weeds adequately.

Some farmers use preemergence herbicides instead of preplant incorporated herbicides. Preemergence herbicides are applied as soon as possible after soybeans are planted but before the soybeans or weeds emerge.

Soybeans are commonly rotary hoed after planting to kill small weeds and to aid soybean emergence if a soil crust develops. Soybeans are usually cultivated twice for weed control.

## The Disk System

If a disk system is used where a soybean crop follows a corn crop, the field is disked in the fall. The primary purpose of this operation is to hasten decomposition of the residue by cutting it into small pieces and mixing it with the soil. Some farmers use a heavy offset disk because it loosens the soil to a greater depth and covers more of the corn plant residue. This kind of disk should not be used for seedbed preparation in the spring.

When using the disk system, you perform essentially the same spring operations as you do with the moldboard and chisel plow systems. With both the chisel plow and disk systems, however, it is generally recommended that the herbicide application rate be increased (but not above the rate listed on the label). The reason for this increase is that these systems leave considerable residue on the soil surface in the spring; the residue may absorb some of the herbicide and otherwise limit its contact with the soil.

## The No-Tillage System

With a no-tillage system, seed is planted in previously undisturbed soil, using a special, heavy planter equipped to plant through residue in firm soil. Weeds growing at planting time are killed with a contact herbicide. The only residual herbicides used are those that can be applied preemergence. Fertilizers and pesticides must be applied to the soil surface or in the narrow, tilled area of the row.

Although no-tillage has received much publicity in recent years, it has been adopted only to a limited extent. No-tillage is most commonly used when soybeans are planted after wheat harvest, a practice referred to as double-cropping.

# Choosing a Tillage System

In deciding which of these tillage systems to use, or whether to use tillage at all, consider carefully the effect of each option on yield, production costs, and soil erosion.

## Crop Residue

Conservation tillage systems leave plant residues on the soil surface that may affect yields. These residues reduce the rate at which the soil warms up in the spring when higher than normal temperatures are necessary for maximum plant growth. Later in the season, lower than normal temperatures are desirable in Illinois, but by that time the crop has developed a full canopy that limits the influence of the residues on soil temperature. Problems caused by surface residues are more severe with early planted corn than with soybeans, which are usually planted after mid-May.

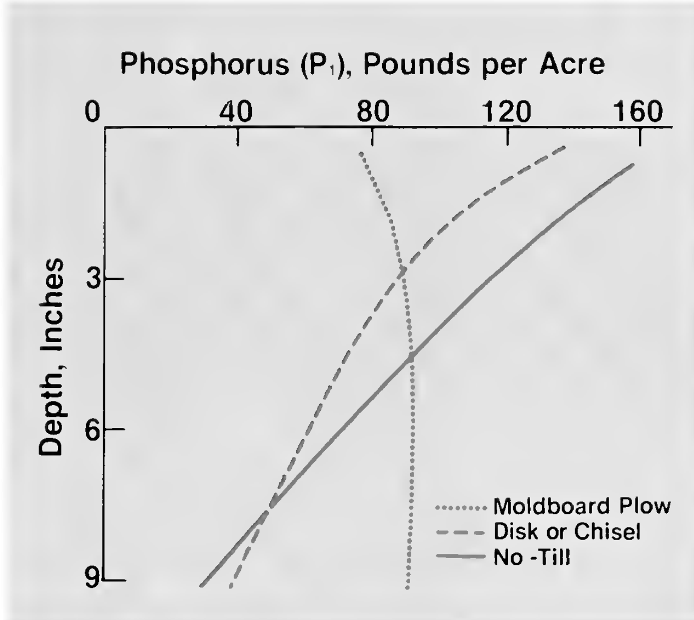
In addition to reducing the soil temperature, plant residues reduce the rate at which moisture evaporates from the soil surface. The resulting excess moisture can be a serious problem in the spring since many Illinois soils tend to be too wet at that time. If there is too much moisture in the soil and the soil temperature is too low, germination may be reduced, and early plant growth will be slowed. During the summer, however, when there is often a shortage of rainfall, any extra moisture caused by plant residues may be beneficial.

The degree to which plant residues are a disadvantage in the spring depends upon the soil type and weather. The effect of excess moisture and low temperatures is more pronounced in heavy-textured, dark soils that have poor natural drainage. On light-colored soils that have good natural drainage, plant growth is usually about the same with the conservation tillage systems as with conventional tillage systems.

## Distribution of Fertilizer

Another consideration that should enter into your selection of a tillage system is its effect upon the distribution of fertilizer in the soil. When you apply phosphorus and potassium fertilizers and lime, the nutrients become attached to soil particles and move very little as water percolates down through the soil. Moldboard plowing uniformly distributes the nutrients in the soil, but the chisel, disk, and no-tillage systems provide very little mixing (see graph at right).

We are not certain if a lack of uniform distribution affects yield. There should be no measurable decrease as long as the soil surface remains moist during the growing season, so roots near the soil surface can remain active. It would seem, however, that during a dry period the soybean plants might suffer. During this period the roots would be active well below the surface where the soil is moist. Since deeper soil would be low in nutrients if a conservation tillage system had been used for several years, yields could be noticeably lower. If you decide to use a conservation tillage system, you may find it necessary to moldboard plow every five years or so to make sure that nutrients are distributed uniformly.




Soil-test values for phosphorus at various soil depths. The moldboard plow system distributes phosphorus more uniformly in the soil than the conservation tillage systems.

## Weed Control

As you assess various tillage systems, consider carefully their effect on weed control. In general, you can expect to have more problems with weeds if you use one of the conservation tillage systems than if you use the moldboard plow system. With conservation tillage more weed seeds are left on the soil surface where they are more likely to germinate and emerge. In addition, the plant residue left on the soil surface reduces evaporation and allows the soil to remain moist enough for weed seeds to germinate for a longer time. But in spite of the increased weed pressure, you can control most weeds effectively when you use a conservation tillage system.

With a no-tillage system you must rely on a contact herbicide to kill weeds that emerge before planting. Where it is likely that a thick stand of grasses will emerge in early spring, you may want to apply a residual grass herbicide before the grasses emerge. A thick stand of grasses will in a short time decrease the soil moisture to such a great extent that soybeans will not germinate until it rains. You should not allow a thick stand of grasses or other weeds to get established, especially in the spring. With other conservation tillage systems, at least two spring tillage operations are usually necessary to kill weeds before planting.

Most soybean producers apply preemergence or preplant incorporated herbicides and use at least two tillage operations. The soil is first disked in the spring to level the soil surface and kill early germinating weeds. If preplant incorporated herbicides are to be used, they are applied next. The herbicides are then incorporated in two tillage operations, usually with a disk or field cultivator. As mentioned previously, other tools can be used to incorporate herbicides.

An alternative to preplant incorporated herbicides is preemergence herbicides. Preemergence herbicides are not incorporated. They are applied either at planting or shortly afterwards. Their main disadvantage is that they are most effective only if it rains shortly after they are applied.

If herbicides fail to control weeds adequately, you can use a rotary hoe after planting to improve the performance of the herbicides and kill weeds that were not controlled by the herbicide treatment. Rotary hoeing also breaks up crusted soil. The rotary hoe can be used with most conservation tillage systems, except perhaps the no-tillage system. Be sure to operate the rotary hoe fast enough (6 to 10 miles per hour), and use it before the soil surface forms a hard, dry, thick crust.

To kill weeds that are not controlled by herbicides or tillage, you should cultivate soybeans with a rolling cultivator, a cultivator with disks and one large sweep per row, or a common sweep cultivator. The first two are perhaps best suited for this purpose becuse they are less likely to plug with residue than the common sweep cultivator.

## Plant Population

Your choice of tillage system will probably have less influence on soybean plant population than on weeds, soil fertility, and other considerations that affect yield. To produce good stands, seeds must be uniformly covered at the right depth (1½ to 2 inches), in moist soil, and with adequate seed-soil contact. With conservation tillage, some seed may come into contact with the plant residue, causing the soil around the seed to dry too rapidly for germination and emergence. You can overcome this problem by using one of the new planters. Improvements in these planters make it possible to obtain good soybean stands even where there is a considerable amount of surface residue. Soybean plant populations are usually about the same with conservation tillage as with conventional tillage systems.

In general, the same can be said about soybean yields, although they may be lower with a conservation tillage system even when good stands and weed control are obtained. We do not know the exact reason. Increased soil compaction and nonuniform distribution of nutrients may be partly responsible, but it has not been shown that these conditions decrease yields in Illinois. Soybean yields with the four major tillage systems in a corn-soybean rotation are listed below, left.

## Costs

To determine the cost of a tillage system, you must calculate the fixed and variable costs for machinery, the labor costs, the costs incurred by untimely field operations, and the costs for pesticides and fertilizers. In comparing the costs of various systems, you need to know the type and size of the machinery for each system, which depends on the size of your farm and the amount of labor available to you. When selecting machinery, consider carefully the scheduling of all operations, so that you can minimize yield losses resulting from untimely operations.

The estimated costs for producing soybeans with the four major tillage systems are listed below, right. You will notice that as you reduce the amount of tillage, machinery costs tend to decrease and pesticide costs increase. Because the decrease in one cost just about balances the increase in the other, all the tillage systems cost about the same.

## Soil Erosion

One of your primary concerns in choosing a tillage system should be soil erosion. Excessive soil erosion occurs on nearly 40 percent of the cropland in Illinois, and the sediment carried by runoff water is the major nonpoint-source pollutant of surface waters in the state. Unless this erosion is reduced to tolerable levels, the productivity of much of the land will be permanently reduced, and the sediment eroded from cropland will continue to cause damage downstream.

The severity of this problem in your operation depends upon the soil type, slope, slope length, crop, and tillage system. Consult *Estimating Your Soil Erosion Losses*, which you can obtain from your county Extension adviser, for a discussion of the effects of these factors upon erosion.

The moldboard plow system is much more conducive to soil erosion than the conservation tillage systems because the moldboard plow covers all the crop residue. Leaving this residue on the soil surface is the primary means by which conservation tillage reduces erosion. Without the protective cover of the residue, the soil in a short time becomes quite smooth as a result of weathering. With the moldboard plow system, the soil is particularly vulnerable to erosion during the winter and spring until the next crop forms a full canopy.

Soil erosion is a more serious problem after soybeans than after corn. One possible reason is that the soybean plants loosen the soil, although neither the reasons for nor the extent of this effect has been documented. Another reason is that the root system of the soybean plant is not nearly as extensive as that of the corn plant. The most important reason, though, is that after soybeans are grown much less residue is left on the soil surface. Only 4,000 pounds of residue per acre is left on the soil after a good soybean crop is harvested, whereas 6,000 to 9,000 pounds remains after a corn crop.

| | Yield, bushels per acre | |
|---|---|---|
| | 5-year average, Urbana | 6-year average, Brownstown |
| Moldboard plow | 44 | 32 |
| Chisel | 41 | 32 |
| Disk | 42 | .. |
| No-tillage | 32 | 30 |

| | Costs of tillage, dollars per acre | | |
|---|---|---|---|
| | Machinery | Pesticides | Total |
| Moldboard plow | 41.04 | 13.51 | 54.55 |
| Chisel | 38.64 | 15.40 | 54.04 |
| Disk | 35.01 | 17.29 | 52.30 |
| No-tillage | 24.40 | 27.28 | 51.68 |

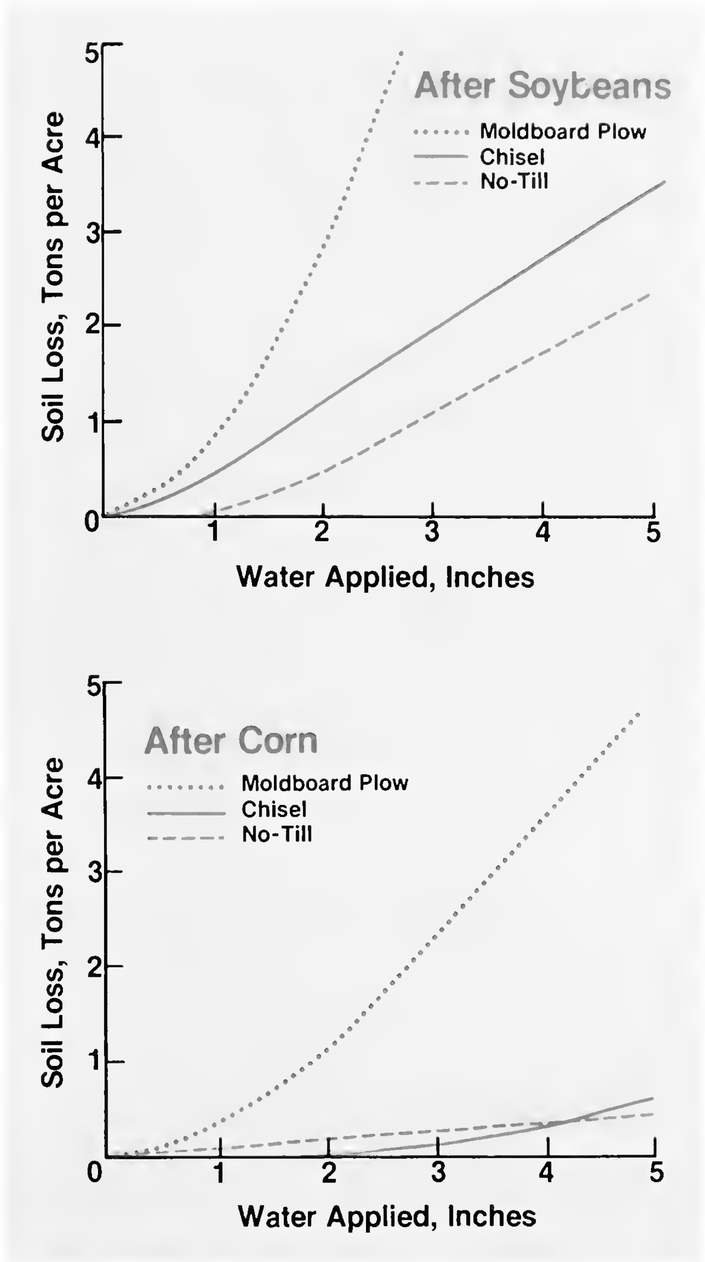
The results of several studies indicate that soybean production is more conducive to soil erosion than corn production. At the University of Illinois, various test plots on which soybeans had been grown were given different tillage treatments after the growing season: moldboard plowing, chisel plowing, and no tillage. During the following spring before any spring tillage operations were performed, intense rain was applied to the plots by means of a rainfall simulator. Similar tests were conducted, using the same tillage operations, on plots where corn had been grown.

As one might expect, negligible amounts of residue were left on the soil surface of the plots that had been moldboard plowed. On the plots that had been chisel plowed there remained only 400 pounds of residue per acre where soybeans had been grown, as compared to nearly 2,000 pounds per acre where corn had been grown. On the soybean plots, it took as little as one spring disking to reduce the amount of surface residue to 400 pounds per acre. Only on the plots that received no tillage in the fall or spring did the amount of residue exceed 2,000 pounds.

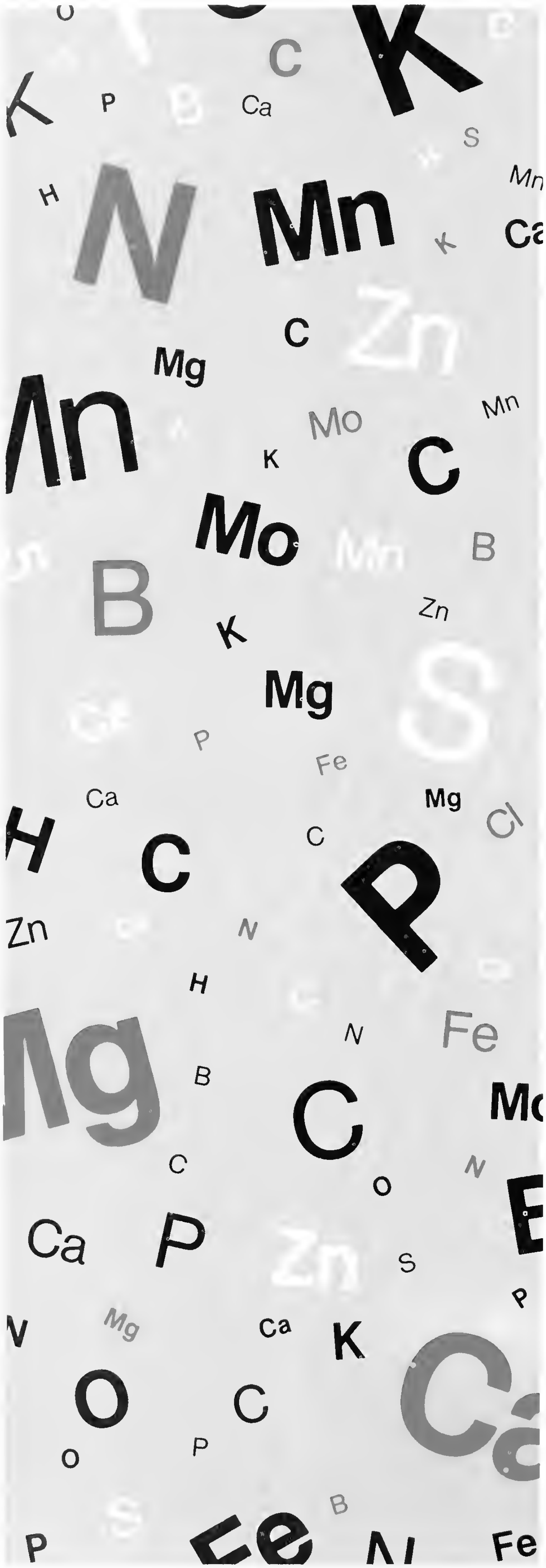
Regardless of which tillage system was used, a higher percentage of the simulated rain ran off where soybeans had been grown than where corn had been the previous crop. The reasons for this difference were fairly obvious. The soil surface was more stable in the corn than in the soybean plots, and it remained rough for a longer period on the corn plots that had been moldboard or chisel plowed. No doubt, the fact that a smaller amount of residue was left on the soybean plots was also a major cause of the higher runoff in those plots.

A similar pattern appeared in the measurements of soil loss (see graphs at right). On the plots that had been moldboard plowed, soil loss was two to three times greater for soybeans than for corn. After soybeans had been harvested, 3 inches of rain caused over 6 tons of soil loss per acre on the plots that had been moldboard plowed, 1.7 tons per acre on the plots that had been chisel plowed, and 0.8 ton per acre where no tillage had been used. On the corn plots, 2.7 tons of soil per acre was lost on the plots that had been moldboard plowed and less than 0.3 ton per acre where chisel plow and no-tillage systems had been used. Excessive soil erosion is clearly much more likely with soybeans than with corn. It also seems fairly obvious that the primary reasons for the greater potential for erosion in soybean production are that relatively little residue is left on the soil surface and that the soil is relatively loose and easily erodible after soybean harvest.

There are several ways to reduce erosion in soybean production. The three principal alternatives are to terrace the land, perform all field operations on the contour, or use a conservation tillage system. In some cases all three may be necessary. Terracing minimizes soil erosion by reducing the lengths of the slopes. As long as the terraces are designed to fit the particular situation, they should be effective. Terracing is expensive, though, and may not be well suited to mechanization. For help in designing terraces, consult your district conservationist of the Soil Conservation Service. Performing field operations on the contour is a less expensive alternative, but in many situations it is not practical and will not provide enough erosion control. As mentioned previously, conservation tillage controls soil erosion effectively because it leaves a rough, stable surface and a protective cover of crop residue.




Soil loss is much greater after soybeans than after corn. With either crop, it is greater with the moldboard plow than with the other tillage systems.



# Fertilization

Soybeans, like all green plants, require 16 different nutrients to complete the metabolic processes necessary for growth and reproduction. A deficiency of any one of these nutrients will reduce soybean yield.

## Plant Nutrients

### Nitrogen

Because soybeans are a high protein crop, they require a large amount of nitrogen for optimum production. One bushel of soybean seed contains about 4 pounds of nitrogen, and for each bushel of seed the soybean plant produces, it requires another 1 to 2 pounds of nitrogen to maintain the vegetative part of the plant. As with most other crops, the primary symptom of nitrogen deficiency is a yellowing of the entire plant.

Since the soybean is a legume, it can symbiotically fix significant amounts of nitrogen. In a study conducted by University of Illinois specialists, properly nodulated soybeans grown at the proper pH symbiotically fixed 63 percent of the nitrogen removed in a yield of 38 bushels per acre. The remaining 37 percent (71 pounds per acre) of the nitrogen removed came from the soil. But even though the net loss of nitrogen from the soil is rather large, researchers have not found that soybean yields increase either because of nitrogen remaining in the soil from previous crops or as a result of nitrogen application.

Application of nitrogen fertilizer reduces the amount of nitrogen that is symbiotically fixed. In one study, soybeans obtained approximately 48 percent of their nitrogen through symbiotic fixation when no fertilizer nitrogen was applied. Application of 400 pounds of nitrogen per acre reduced fixation to 10 percent of the total amount assimilated by the plant. The results of this study indicate that nitrogen is symbiotically fixed only if it is needed by the soybeans and that fertilizer nitrogen added for nonlegumes, but not removed by them, can be absorbed by soybeans that follow in the cropping sequence.

To obtain nitrogen from the atmosphere, soybeans must be well nodulated with effective strains of Rhizobium bacteria. If soybeans have been recently grown in the field and were well nodulated, inoculation is probably not necessary. Soybeans should be inoculated with Rhizobium bacteria if they are to be planted in a field where soybeans have not previously been grown. It is probably also a good idea to inoculate if soybeans have not been grown on the soil for five years or more.

Attempts have been made to introduce more effective strains of bacteria into the soil. However, researchers at Iowa State University have shown that if the inoculum Rhizobia are to form 50 percent or more of the nodules they must be introduced at a rate at least 1,000 times the population of the bacteria in the soil.

Because Rhizobium inoculums contain live organisms, you must take certain measures to ensure that you derive the maximum benefit from them. Be sure to plant the seed soon after you inoculate. You should not inoculate seed weeks or months before planting because the live Rhizobia will decrease in number over time. After inoculating the seed, allow it to dry; wet seeds can cause planting problems. To avoid reducing the number of live Rhizobia, do not expose inoculated seeds to sunlight, high temperature, or severe drying conditions.

Until nodulation occurs, the soybean plant depends upon the nitrogen in the soil for growth. Some specialists have suggested that by applying a small amount of starter nitrogen fertilizer, you might enhance the early vegetative growth of soybeans. In some cases, this practice makes earlier cultivation possible and results in better weed control. It is most likely to produce results on soils in which little nitrogen is present early in the spring. But under normal conditions, where an adequate amount of nitrogen is in the soil, soybean yield does not respond consistently to the application of small amounts of nitrogen in starter fertilizer.

## Phosphorus

A soybean crop that yields 60 bushels per acre requires approximately 65 pounds of phosphate ($P_2O_5$) in the seed and vegetative parts of the plants. More than 50 pounds of this $P_2O_5$ is removed in the seed. Phosphorus helps stimulate early root formation and growth. Plants that have an adequate amount of phosphorus will start more rapidly and vigorously than plants that are deficient in phosphorus.

Although phosphorus is involved in many important metabolic processes in the plant, a deficiency of phosphorus does not produce a characteristic symptom as deficiencies of other nutrients do. Usually, phosphorus deficiency results in an overall lack of vigor or simply in smaller plants. Since there are no clear symptoms by which to identify the deficiency, the most reliable means of anticipating it is an adequate soil testing program.

Phosphorus deficiency usually occurs early in the spring because the root systems of the soybean plants are not yet extensive enough to absorb much of the nutrient. Uptake of phosphorus is further reduced by the cooler soil temperatures that usually occur at that time. As the root systems develop and soil temperature rises, however, uptake of phosphorus increases, reaching a peak just prior to pod initiation and continuing until the beans are nearly formed.

Because phosphorus uptake occurs throughout much of the growing season and because it is an immobile nutrient, you should make sure that high levels of phosphorus are present throughout a large part of the rooting zone. It has been suggested with some validity that soybeans respond less to direct application of phosphorus than do many other crops, such as wheat and corn. But if soil testing shows that the soil is deficient in phosphorus, direct application does increase soybean yield, as shown in the graph on page 10.

Soybeans absorb nutrients from the soil very efficiently. In fact, researchers at Iowa State University have found that soybeans produce maximum yield at lower soil-test or applied-phosphorus levels than corn. For that reason, application of phosphorus has a greater effect on corn than on soybean yield. However, once the fertility of the soil is raised to an adequate level, further application of phosphorus to either crop produces no additional increase in yield. The extra fertilizer serves merely to maintain an adequate level of phosphorus in the soil.

Nearly all the phosphate fertilizers available in Illinois are manufactured from rock phosphate. These manufactured materials are high in water solubility and in total availability (see table on page 10). Under typical field crop and soil conditions, the small differences among commonly sold materials in the water solubility of the $P_2O_5$ (listed on the fertilizer label) are of little importance.

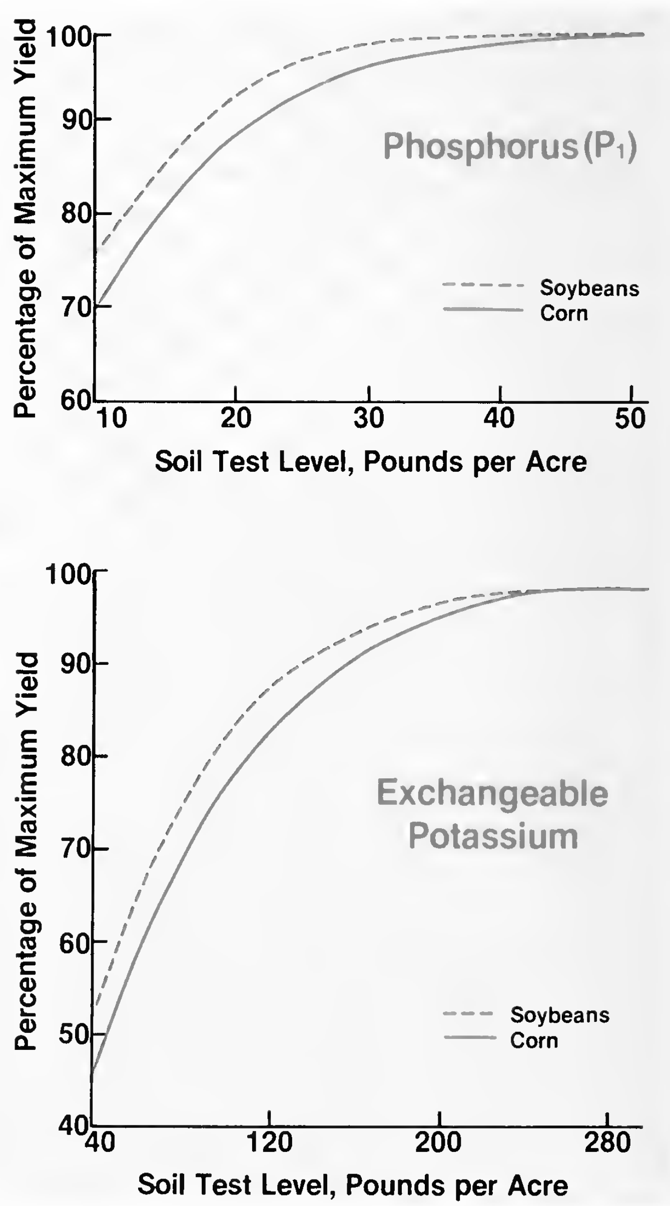
| | Total percentage of nitrogen | Total percentage of phosphorus ($P_2O_5$) | Percentage of total available | Percentage of total water soluble |
|---|---|---|---|---|
| Ordinary superphosphate | 0 | 16 to 22 | 97 to 100 | 78 |
| Triple superphosphate | 0 | 43 to 47 | 96 to 99 | 84 |
| Ammonium phosphate (mono) | 11 | 48 | 100 | 100 |
| Diammonium phosphate | 18 | 46 | 100 | 100 |
| Ammonium polyphosphate (granular) | 15 | 61 | 100 | 100 |
| Ammonium polyphosphate (liquid) | 10 to 11 | 34 to 37 | 100 | 100 |

## Potassium

A soybean crop that yields 60 bushels per acre contains 78 pounds of potassium oxide ($K_2O$) in the seed and requires an additional 67 pounds of $K_2O$ for vegetative growth. The primary symptom of potassium deficiency is an irregular, yellow mottling around the edges of the leaflets, particularly in the lower parts of the plants. As the deficiency becomes more severe, the chlorotic areas merge to form continuous yellow borders around the tips and along the sides of the leaves (for a color photograph, see page 45).

The most accurate way to determine whether potassium is needed in a particular field is through soil testing. An increase in the soil-test level of potassium affects soybean yield much as it does corn yield (see graph at right). For that reason, most agronomists in the Midwest suggest that the soil-test level be kept about the same for both corn and soybean production.

Potassium chloride (0-0-60) is the principal source of potassium fertilizer in Illinois. Other sources are potassium sulfate, potassium magnesium sulfate, potassium nitrate, and potassium phosphate. Because potassium chloride is the least expensive source, it is probably the best choice, unless your soil needs one of the other elements associated with potassium.




Percentage of maximum soybean and corn yields that can be obtained at various soil-test levels of phosphorus, top, and exchangeable potassium, bottom.

## Calcium and Magnesium

Most soils in Illinois have an adequate amount of magnesium for crop production. Since all liming materials contain calcium, your soybean crop should not be deficient in this nutrient as long as you maintain the pH of the soil at 6.0 or above. Calcium and magnesium deficiencies are especially unlikely in many parts of central and northern Illinois because farmers there use dolomitic limestone, which contains both calcium and magnesium, to correct soil acidity.

Some soils in southern Illinois have only marginal levels of magnesium in the surface layers, but this lack of magnesium does not appear to be a serious problem. Researchers at Southern Illinois University have reported that applying magnesium to soils with marginal to low levels of this nutrient did not affect yields. The reason soybean yields were not affected, these researchers believe, is that there were adequate levels of magnesium in the subsoil.

Some agronomists are concerned that applying excessive amounts of potassium to soils that have marginal levels of magnesium may create an imbalance between these two nutrients. Although such an imbalance could occur, so far research has not shown that yields are depressed by application of large amounts of potassium, even in areas where the magnesium level is marginal to low. Nor has research confirmed that higher levels of potassium are necessary on soils having a high level of magnesium.

## Sulfur

A soybean crop that yields 60 bushels per acre contains approximately 25 pounds of sulfur in the entire plant. Nearly 60 percent of this sulfur is harvested in the seed.

Although there is little documented evidence of sulfur deficiency in soybeans in the Midwest, the potential for deficiency may increase in the future for several reasons: air quality standards have markedly reduced the amount of sulfur the soil receives from the atmosphere; less sulfur is added as a by-product in fertilizers or pesticides; and as soybean yield has increased, crops have removed more sulfur from the soil.

Under Illinois conditions, the sulfur soil test currently being used has not proven reliable. In recent studies, many of the sites that this test predicted would respond to sulfur applications did not actually need sulfur. To determine the need for sulfur accurately, you should use soil tests in conjunction with plant analysis.

When a need for sulfur fertilizer becomes apparent, you can apply any one of a number of different sources of sulfur, including various sulfate salts of potassium, calcium, potassium-magnesium, and ammonium; thio-sulfate; and elemental sulfur.

## Boron

Boron occurs in most soils in small quantities. Most of it is held by the organic fraction of the soil. The amount of boron available for plants depends upon the rate at which the organic matter decomposes and the ability of the soil to retain boron within the rooting zone. Because the form of boron available to plants is an anion, it is readily leached in soils in which water moves rapidly through the profile. Leaching occurs most readily in sandy soils. These soils have little organic matter and a relatively small inherent supply of boron. As a result, boron deficiency is much more likely in sandy soils than in the heavier-textured soils that have more organic matter.

Although the exact relationship between soil pH and the availability of boron has not yet been completely defined, research has clearly shown that boron is less available at higher pH. In a study conducted by University of Tennessee specialists, application of boron significantly increased soybean yield on a sandy soil that had a pH of 7.1. But boron application had no effect on yield where the pH was 6.6 or lower.

Throughout the United States, application of boron has had an extremely limited effect on soybean yield. For that reason, and also because there is a narrow margin between sufficient and toxic levels of boron, you should not apply boron to soybeans unless you perceive a definite need for this nutrient in a particular field.

## Chlorine

So far, deficiency of chlorine has not been observed in soybean fields in the Midwest. And it is unlikely that any deficiency will develop since a considerable amount of chlorine is added to the soil each year in potassium fertilizers and rainfall. In many parts of the Midwest, the amount of chlorine added through precipitation is more than adequate for most crops.

## Copper

Most copper deficiencies identified in the United States have occurred either in highly weathered, sandy, mineral soils or in soils that are high in organic matter. Analysis of the vegetative portion of the plant does not appear to be a good indicator of copper deficiency. Similarly, little data is available showing a correlation between the results of a copper soil test and yield response to copper application.

| Variety | Chlorosis score* |
|---|---|
| **Maturity group I** | |
| Hark | 5 |
| Hodgson | 2 |
| Hodgson 78 | 2 |
| **Maturity group II** | |
| Amsoy 71 | 3 |
| Beeson | 3 |
| Beeson 80 | 3 |
| Century | 2 |
| Corsoy | 4 |
| Corsoy 79 | 4 |
| Gnome | 4 |
| Nebsoy | 4 |
| Wells | 3 |
| Wells II | 3 |
| **Maturity group III** | |
| Calland | 2 |
| Cumberland | 4 |
| Oakland | 4 |
| Pella | 4 |
| Wayne | 5 |
| Williams | 3 |
| Williams 79 | 3 |
| Will | 3 |
| Woodworth | 4 |
| **Maturity group IV** | |
| Bonus | 3 |
| Crawford | 4 |
| Cutler 71 | 3 |
| DeSoto | 3 |
| Franklin | 2 |
| Kent | 4 |
| Pomona | 4 |
| Union | 3 |
| **Maturity group V** | |
| Essex | 3 |

* 1 = low susceptibility (plants appear green to slightly yellow); 5 = high susceptibility (plants appear yellow and stunted).

## Iron

Iron deficiencies have been observed in Illinois ever since the introduction of Wayne, Hark, and other susceptible soybean varieties. The deficiency occurs almost exclusively on soils having a pH well above 7. In these soils a form of iron develops that is not available to plants. As a result, a deficiency can occur even when the total amount of iron in the soil is adequate for crop production.

The main symptom of iron deficiency is interveinal chlorosis (the leaves turn yellow, while the veins remain green). As the deficiency worsens, the leaves eventually turn more nearly white (for a color photograph, see page 45).

Because soybeans often outgrow the symptoms of iron shortage, it has been difficult to measure yield losses or decide whether or how to treat affected areas. Researchers recommend that iron be applied to leaves as iron chelate at a rate of 0.15 pound per acre within 3 to 7 days after symptoms of chlorosis appear (usually in the second trifoliate stage of growth). If you wait for soybeans to reach the fourth or fifth trifoliate stage before applying iron, the application will probably not increase yield.

Whether you have problems with iron deficiency depends in part on the soybean varieties you grow. The susceptibility of selected varieties to iron deficiency is shown in the table at left. Be sure to consider this factor when selecting varieties, especially for fields with high soil pH.

## Manganese

Both manganese toxicity and deficiency have been observed in Illinois. Toxicity may occur under good growing conditions on extremely acid soils that have a pH of less than 5.2. The symptoms of toxicity are cupping and crinkling of leaves and stunting of plant growth. This condition can best be corrected by liming the soil to increase the pH to an adequate level.

Manganese deficiency is most likely to occur during cool, wet weather in late May and June on soils that have a pH greater than 7.2. Like iron deficiency, it occurs in most cases because high pH makes manganese unavailable to plants. Deficiency does not usually occur because the total supply of manganese in the soil is insufficient.

The primary symptom of manganese deficiency is yellow interveinal chlorosis. As the deficiency worsens, necrotic or rust-colored spots appear on the leaves (for a color photograph, see page 45). The most reliable means of detecting manganese deficiency is to test the soil pH, conduct plant analysis, and watch for symptoms.

## Molybdenum

Plants require only small amounts of molybdenum. Because this nutrient is essential to nitrogen fixation, the symptoms of deficiency are similar to those of nitrogen deficiency. These symptoms usually do not occur, however, if the soil has enough nitrogen to make up for the absence of symbiotic fixation.

Molybdenum differs from most other micronutrients in that it becomes more readily available as the pH of the soil increases. In Illinois, the only molybdenum deficiency observed has occurred on extremely acid soils in southern Illinois. In nearly all cases, it is more economical and productive to apply limestone to correct soil acidity than to apply molybdenum continuously.

## Zinc

When zinc deficiency occurs, plant growth is stunted, and the leaves turn yellow or light green. The lower leaves may turn brown and drop. Flowering is usually markedly reduced. Any pods that set are abnormal and mature slowly.

Zinc deficiency is most likely to occur on sandy soils that are high in pH and phosphorus and low in organic matter. If you grow soybeans on soils with these characteristics and your yield is less than expected, you should check the field for zinc deficiency. Soil tests are available, but they are not highly reliable. To determine accurately the need for supplemental zinc, you should use the soil test in conjunction with plant analysis. If both tests indicate a low level of available zinc, apply zinc on a trial basis.

Several sources of zinc are available. On fields that have either high pH or high levels of phosphorus, use chelated zinc materials, or apply an inorganic zinc source with an acid-forming starter fertilizer. These applications will probably have a greater effect on yield than will a broadcast application of an inorganic zinc source.

## Limestone

Maintaining the proper soil pH is extremely important in the production of any crop. But because soil pH is directly related to nitrogen fixation, keeping it at the proper level is especially important in the production of leguminous crops such as soybeans. You can derive a number of benefits from liming: (1) it makes some micronutrients and both the native phosphorus in the soil and that which is applied to the soil more readily available to plants; (2) it reduces the toxicity of manganese and aluminum; (3) it enhances the activity of the nodule-forming bacteria that are responsible for nitrogen fixation and several microorganisms that decay plant residue and release plant nutrients; (5) it improves root growth; and (6) it adds the essential element calcium and, if dolomitic limestone is used, the essential element magnesium.

The optimum soil pH for soybeans is between 5.8 and 7.0. Most agronomists recommend that the soil pH be maintained at or slightly above 6.0. If a soil test shows that the pH is 6.0, apply limestone to prevent it from dropping below 6.0. You may want to raise the pH to an even higher level. Once you have made the initial investment in limestone, it costs little more to maintain a pH of 6.5 than it does to maintain a pH of 6.0. Your profits over a ten-year period will be affected very little since the increased yield will just about offset the cost of the extra limestone plus interest.

Soil testing is the best means available for anticipating lime needs. To determine this need accurately, test one sample from every 4 to 5 acres in each field. The amount of limestone you apply depends on the degree of soil acidity, the soil type, and on the quality of the limestone. When purchasing limestone, you should know the calcium carbonate equivalence and fineness of grind of the material. You can then calculate the effective neutralizing value of the liming material.

Most of the agricultural limestone currently available is a dry-ground, natural rock. In recent years, however, fluid lime suspensions have been developed. Sometimes referred to as "liquid lime," these suspensions consist of limestone particles ranging from 200 to 325 mesh suspended either in a water or nitrogen solution. Formulations of fluid lime suspension with as much as 70 percent solid by weight are available, but formulations of 50 percent lime and 50 percent water are more common. Because the lime in these formulations is finely ground, it will correct soil acidity rapidly. Even so, to correct the acidity of a particular soil and maintain the proper pH, you will have to apply about the same amount of limestone regardless of whether you apply a liquid suspension or a dry source of limestone.

# Methods of Fertilizer Application

The three principal methods of applying fertilizer are broadcast, row placement (band), and foliar application. The method you choose depends on the crop, the particular nutrient being applied, the soil characteristics, and to a limited extent your land tenure arrangements.

Most producers throughout the Midwest apply fertilizer by the broadcast method. This method has several advantages over the other two. It creates less potential for crop injury from salt; it is less time-consuming; it requires less labor; and because the fertilizer is handled in bulk, this method is generally less expensive. In addition, nutrients that are broadcast and thoroughly incorporated into the root zone are more readily available during dry periods.

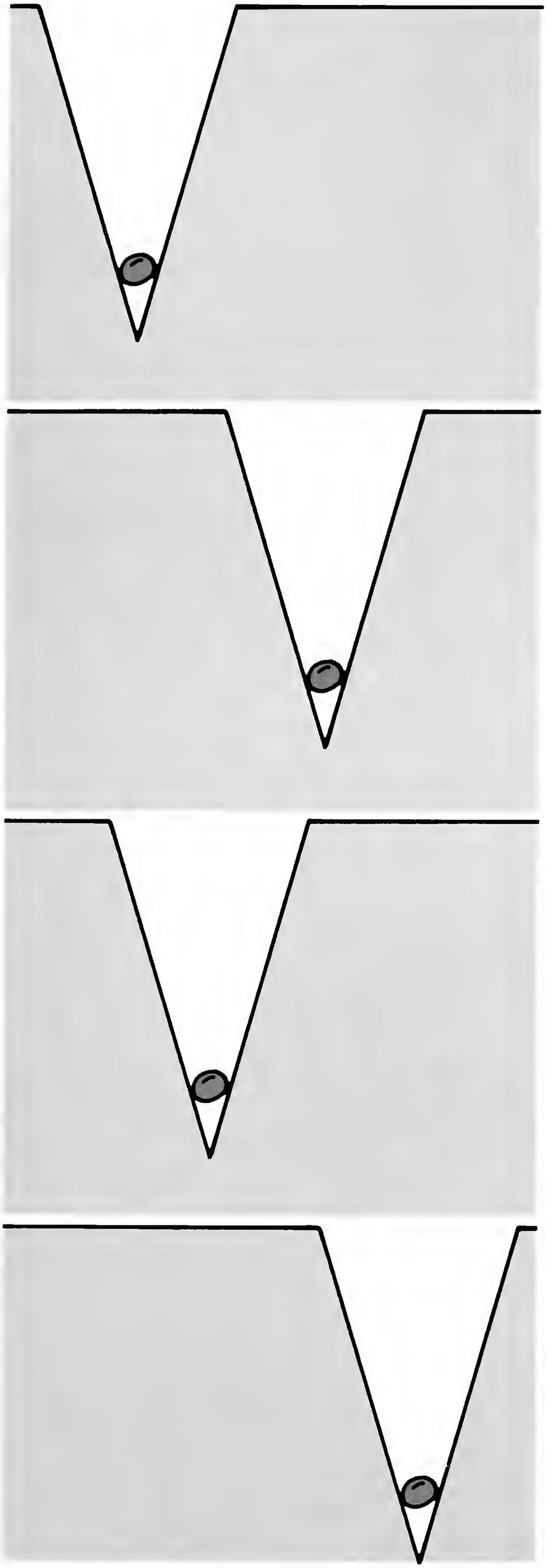
The primary disadvantage of broadcasting is that it increases the soil-fertilizer contact, which increases the potential for phosphorus fixation in either strongly acid or strongly alkaline soils. As a result, during the first year you broadcast fertilizer, the materials may not be used as efficiently as they would if you had band applied them. In subsequent years, however, phosphorus not used the first year will be available to the plants.

The chief advantage of row or band placement of fertilizer is that the materials are more efficiently used by the crop the first year of application. By concentrating the nutrients in a small band within the soil, this method allows less fixation of phosphorus and to some extent potassium, especially on soils that have extremely low fertility levels or that are either highly acid or highly calcareous.

Always place row fertilizers at least 2 inches away from the seed, never in direct contact with it. Researchers at the University of Wisconsin found that on a silt loam soil direct contact between fertilizer and seed markedly reduced soybean stand when the total amount of phosphorus and potassium exceeded 9 pounds per acre or when the rate of nitrogen and phosphorus or nitrogen and potassium exceeded 6 pounds per acre.

Plants absorb and use fertilizer most efficiently when it is foliar applied. But because the fertilizer cannot be applied efficiently by this method, it is not practical for maintaining the entire fertility program of most agronomic crops, including soybeans.

The results of research conducted so far indicate that foliar application of major nutrients does not raise the potential for yield increase enough to be economically justified. Further research is needed to identify the conditions under which foliar fertilization might be practical. We already know that it can be effective in correcting deficiencies of many micronutrients. Since most of these micronutrients are required in fairly small amounts, you can easily supply them through foliar feeding without causing foliar burn. In many cases, if you make a foliar application of a micronutrient soon after you recognize the deficiency, you can obtain nearly optimum yield.



# Planting

## Plant Density

There is no ideal plant density for soybean production. Soybeans can grow and produce quite well in Illinois over a broad range of plant densities. Whether you select a seeding rate that will produce a plant population nearer the upper or lower limit of this range depends upon the variety you plant and the conditions in your fields.

You can seed a variety that is resistant to lodging at a higher rate than one that shows a marked tendency to lodge. Planting a variety resistant to lodging is especially important if your fields are highly fertile and have ample supplies of water. These conditions increase the likelihood of lodging and may necessitate a reduction in the seeding rate.

Planting seed at a rate that increases the plant density above the appropriate range may reduce your soybean yield. When stands are too thick, the stems of the plants weaken and become highly susceptible to lodging. Excessive plant density also reduces the number of pods per plant. The lower pods on the plant are particularly likely to abort.

When plant density is below the lower limits of the acceptable range, each plant tends to produce more branches. These branches may develop numerous pods, compensating somewhat for the lower plant density. But because many of the pods will form close to the soil line, you may not be able to harvest them.

If you plant seed at an extremely low rate, the crop may not be dense enough to intercept the sunlight fully. The sunlight will fall upon the soil surface, promoting weed growth and excessive evaporation of soil moisture.

Some suggested ranges of plant density for various row spacings are listed below (these plant densities are for conventional spring seeding dates). The seeding rate depends on seed quality, field conditions, seeding device, seeding date, and row spacing.

| | Plant density | |
|---|---|---|
| Row spacing, inches | Thousands of plants per acre | Plants per foot of row |
| 40 | 130 to 156 | 10 to 12 |
| 30 | 104 to 139 | 6 to 8 |
| 20 | 104 to 156 | 4 to 6 |
| 10 | 157 to 210 | 3 to 4 |
| 7 | 150 to 225 | 2 to 3 |

## Seed Quality

One important aspect of seed quality to consider is the percentage germination. Be sure you know the germination score of the seedlot. If germination is 90 percent, one in ten seeds will never germinate. To compensate for these nonviable seeds and obtain the desired stand, you must increase the seeding rate. (Germination and other aspects of seed quality are discussed more fully on pages 20 to 22.)

## Field Conditions

A finely prepared seedbed favors germination and plant establishment. In poorly tilled soil, good seed-soil contact at planting is less likely, and the probability that a given seed will germinate and become an established plant is reduced. You may have problems with reduced seed-soil contact and germination if you use a conservation tillage program.

## Seeding Device

In Illinois, most soybeans are seeded with row units. These units tend to distribute the seed more uniformly within the row than drills. In addition, they generally place the seed and cover it more consistently. A definite drawback of row units is that they limit the degree to which rows can be narrowed. For that reason, you almost always have to plant soybeans with a drill if you want to place the rows less than 20 inches apart.

The kind of seeding device you use can have a significant effect upon the seeding rate. Some producers use older grain drills to establish solid-seeded soybeans. The problem with these drills is that they may not always place and cover the seed properly. And because they may not have slow-meter drives, they can damage much of the seed. Since seed damage and poor placement and coverage of the seed reduce germination, it is often necessary with this equipment to plant seed at relatively high rates.

You can avoid this problem by using one of the newer drills now being marketed by a number of equipment manufacturers. Because these drills maintain better depth control than the older drills and are sometimes equipped with press wheels, they can place and cover the seed better. The newer drills also have seed metering devices that enable them to deliver soybeans accurately at the specified rate without causing much damage to the seeds.

## Seeding Date

Late-seeded soybeans tend to yield less than those planted early in the spring (see graph on page 17). One problem with seeding soybeans later in the growing season is that moisture deficiency is more likely to occur then. If the moisture level in the upper soil layer is depleted, the seed will not germinate. Soybeans that are seeded in late June or early July (as in a double-crop program) may not germinate until it rains.

Another drawback to late planting is that the crop canopy will not develop fully enough by the time flowering begins. Soybeans begin to flower when the days become sufficiently short (actually, when the nights become sufficiently long). At that time the soybean plants must have enough vegetation to carry out photosynthesis for the development of pods and seeds. If you select a soybean variety that is adapted to your area and plant it in early spring, the crop will grow considerable vegetation before flowering. But if you delay planting, the plants will have less vegetation and will be less able to use the available sunlight.

To enable double-crop soybeans to intercept all the available sunshine, you must increase the seeding rate, boosting the plant density above those listed on page 15. If you plant soybeans in late June or early July, you should increase the seeding rate 50 to 75 percent over the rate required for May seeding. It is also a good idea to plant double-crop soybeans in narrow rows. This practice has been proven to increase yield. The list below shows the effect on yield of high plant density and narrow rows in double-crop soybeans.

| | Plants per foot of row | Yield, bushels per acre |
|---|---|---|
| Amsoy (20-inch rows) | 5 | 42 |
| | 8 | 59 |
| | 11 | 52 |
| Amsoy (30-inch rows) | 5 | 37 |
| | 8 | 47 |
| | 11 | 51 |
| Wayne (20-inch rows) | 5 | 39 |
| | 8 | 48 |
| | 11 | 61 |
| Wayne (30-inch rows) | 5 | 40 |
| | 8 | 43 |
| | 11 | 53 |

## Row Width

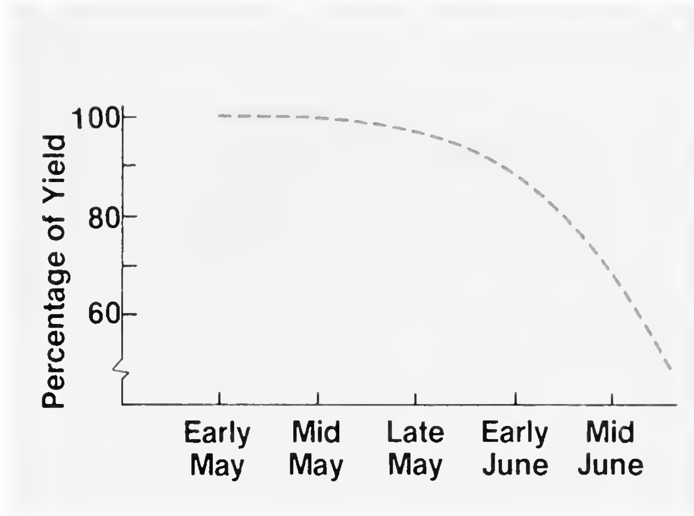
Illinois producers have begun to recognize the benefits of planting soybeans in narrower rows than those used in the past. (Surveys conducted by the Illinois Crop Reporting Service have confirmed this trend.) Years ago when farm implements were still drawn by horses, 38- or 40-inch spacing was suitable for row crops. But in modern agriculture such wide row spacing is not necessary. Today, growers can increase their soybean yield by planting in rows spaced 30 inches or less.

When you plant soybeans in narrow rows, fewer days are required for the crop canopy to develop completely and begin shading the soil fully. Listed below is the number of days it takes for soybeans in wide and narrow rows to achieve full shading of the soil (these figures are from research conducted at the University of Nebraska). When the soil is fully shaded, the crop will intercept all the available sunlight. The earlier it begins to do so, the more total sunlight energy the crop will have to produce its yield, and the more difficult it will be for weeds to become established and compete with the crop. In addition, less moisture will evaporate from the soil surface if the row middles are shaded at an early date. The extent of canopy development and the amount of shading the canopy provides at a given time in the season may vary with the variety, row spacing, planting date, and plant density. The photographs at right show the effect of row spacing upon the development of the crop canopy.

| Row width, inches | Number of days until full shading of soil |
|---|---|
| 10 | 36 |
| 20 | 47 |
| 30 | 58 |
| 40 | 67 |

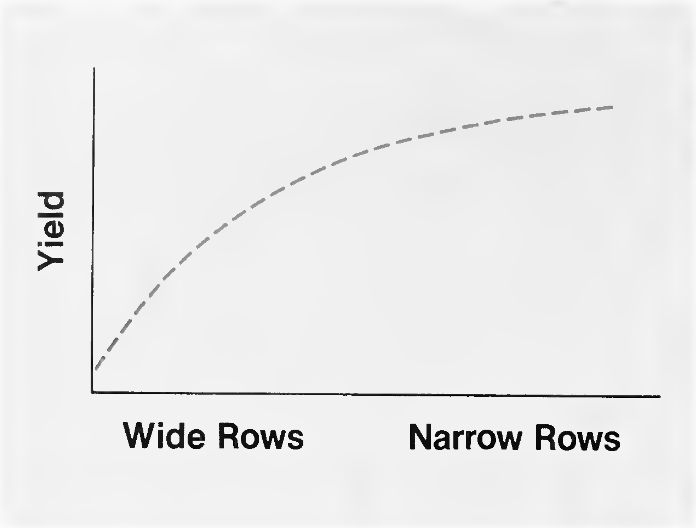
Reducing the row spacing in soybeans may require an increase in the plant population. Where soybeans are drilled solid or planted in some other noncultivated row arrangement, this slightly higher population may be desirable to aid in the development of a full stand that will suppress weeds.

Some growers increase their plant densities by far too much when they reduce their row spacing and as a result have increased lodging problems. Although many producers attribute this increased lodging to the narrow row spacing, it is in fact due to the greatly increased plant density. To minimize this problem, you should limit your increases in plant density to 15 to 20 percent.




The best time to plant soybeans is early to mid-May. Delayed planting may reduce yields sharply.

The soybean field shown at top was solid seeded. As a result, it developed a full canopy much more quickly than the field shown at bottom, which was planted in wide rows.




The effect of row spacing upon soybean yield.

Soybeans planted in a skip-row pattern. Some wide rows are left among the narrow rows, so that there will be enough room for the tractor tires during mechanical weed control operations.

Across the Midwest a number of studies have been conducted to determine the effect of row spacing upon soybeans. The results of these studies are depicted in the graph above. Planting in rows a few inches narrower than the traditional wide rows produces striking yield increases. As the rows are further narrowed, however, the yield increases tend to diminish. When the row spacing is reduced to less than 15 inches, the yield of most varieties increases little, if any, although in certain environments the yield of some varieties will continue to increase.

You will undoubtedly benefit by narrowing soybean rows at least to 30 inches. This row spacing is also suitable for corn. Whether you profit from further decreases in row spacing depends upon your weed problems, the equipment available to you, the soybean variety you grow, and your location.

If you have problems with weeds, such as perennials, that cannot be controlled with herbicides alone, you may not be able to plant soybeans in narrow rows. Once you reduce the row spacing to a width narrower than that required for the operation of your equipment, you cannot cultivate for weed control. The minimum amount of space required for interrow cultivation depends, of course, upon the type of equipment you have. Most modern tractors require a minimum of 30 inches, although with some equipment you can cultivate soybean fields in which the row spacing is less than 30 inches at least once for weed control.

Some producers have solved the problem of using modern farm machinery in narrow rows by adopting a modified planting pattern called the "skip-row" method. When using this method, you leave some wide row spaces among the narrow rows, so that there will be enough space for the tractor tires. You can thus realize the benefits of narrow rows over almost the entire field while permitting the operation of equipment after stand establishment. The photograph at left shows soybeans planted in a skip-row pattern.

The yield increase you derive from your narrow-row program depends in part upon the variety you choose. Many soybean varieties have been used in studies of narrow-row production. It seems that not every soybean variety responds in the same way to reductions in row spacing. For a given location, early maturing varieties are more likely than full-season varieties to yield more in narrow rows. If you are planting soybeans in narrow rows only on part of your farm, you should plant your earliest maturing varieties in that part. Keep in mind, also, that the farther south you are located the less likely it is that the varieties adapted to your area will show a yield increase in narrow rows.

Choosing planting equipment is an important part of getting into narrow-row soybean production. You may want to consider either the drill or unit planters. Unit planters often produce better stands than the drill because they give better seed-soil contact in many seedbeds. But with unit planters the degree to which you can narrow soybean rows is limited. In addition, the cost of a number of unit planters may exceed that of the grain drill. One alternative is to add planter units to your present equipment. The alternative you choose will depend on the kind of equipment you now own, the row spacing you desire, and the amount of capital you have to invest.

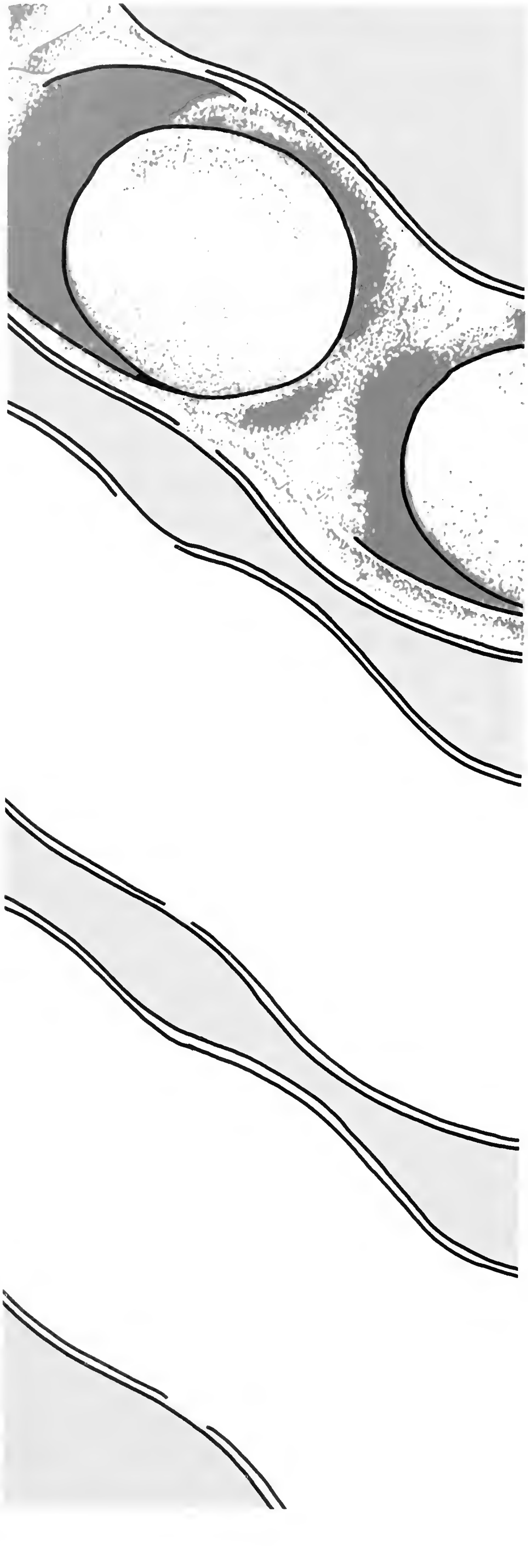
## Crop Rotation

To realize fully the benefits of narrow-row production, you should plant soybeans in rotation with other crops rather than grow them continuously. Some soybean producers believe that it is more economical to grow continuous soybeans in some fields. But, in fact, this kind of production, because it lowers soybean yield and is conducive to major pest problems, often increases production costs in the long term. Crop rotation, in contrast, increases soybean yield and reduces the likelihood that a major pest will become established in your fields.

The list below shows how much both corn and soybean yields increase when these crops are produced in rotation rather than on a continuous basis.

| | Yield, bushels per acre |
|---|---|
| Corn after corn | 113 |
| Corn after soybeans | 126 |
| Soybeans after corn | 44 |
| Soybeans after soybeans | 38 |

Although we do not fully understand why crops in rotation produce higher yields, we are certain that crop rotation is advantageous and that producers should practice it whenever possible. Field studies have clearly shown that crop rotation is associated with reductions in certain weed, insect, and disease problems (for a more detailed discussion of crop rotation and its effect upon plant diseases, see page 32). For example, large populations of soybean cyst nematode (SCN) tend to be starved out during years when some crop other than the host is planted. Although crop rotation may not prevent SCN from infesting a given field, it should reduce both the rate at which the nematode population grows and the degree of injury it causes to soybeans. In addition to reducing pest problems, crop rotation may increase yields in other ways of which we are not yet aware.



# Seed Quality

The quality of seed is determined by its varietal purity, its ability to germinate, its freedom from disease, and by the quantity of inert matter, seed of other crops, and weed seed in it. The production and preparation of high quality seed requires special care and conditioning equipment. To maintain varietal purity, you must clean the planters, combine, transporting equipment, and storage bins thoroughly whenever you switch to a different variety. Weed seed, seed of other crops, and inert matter must be removed by conditioning equipment. The removal of small and very large seed is also desirable. These steps take extra time, effort, and expense, but they pay off in cleaner fields and higher yields.

If you are unable to devote this extra time and effort to seed production, you should purchase the seed you plant from a reputable seed seller that produces high quality soybean seed. To help you judge the quality of seed offered for sale, the Illinois Seed Law requires that the seller of seed provide you with certain information. Bagged seed must have a label that lists (1) the name and address of the person or firm that labeled the seed; (2) the kind of seed; (3) the seed lot number; (4) the variety of the seed (if the variety or varieties are not named, as is often the case with blended seed, the words "variety not stated" must appear on the label); (5) the percentage germination (6) the month of the germination test; (7) the percentage by weight of pure seed; (8) the percentage by weight of inert matter; (9) the percentage by weight of seed of other crops; and (10) the percentage by weight of weed seed. If the seed is in containers, the label must also list the net weight. Be sure that you receive this important information before you purchase the seed. If you buy seed in bulk, the seller should provide you a label listing the information. A sample seed label is shown on page 21.

All of the information on the label is helpful because you cannot judge the quality of seed by its appearance alone. For instance, there is no visible seed characteristic that distinguishes Wells II from Wells. Yet, unlike Wells, Wells II has resistance to phytophthora rot, a characteristic that may be important to you.

**Sample Seed Label**

Variety and kind of soybeans
Name of seed seller
Address

| | | | |
|---|---|---|---|
| Pure seed | _______% | Date of germination test | |
| Weed seed | _______% | | |
| Seed of other crops | _______% | Net weight | _______lb. |
| Inert matter | _______% | Lot number | |
| Noxious weed seed (rate of occurence) | _______ | Germination | ______% |

## Varietal Purity

Most of us cannot distinguish one soybean variety from another if they have the same hilum color and seed luster. For that reason, you must be certain of the integrity of the seed seller. You cannot be sure that all the seed offered you, or at least most of it, is the variety it is claimed to be unless special care has been exercised during planting, harvesting, cleaning, and storing to prevent mixing of different varieties. Extreme care is especially necessary if more than one variety is produced on the same farm and handled with the same equipment.

A good way to ensure that you get the variety you want is to buy seed that is certified by the Illinois Crop Improvement Association. This organization records the sources of seed and inspects both the growing crop and the harvested seed. Certification assures you of the genetic purity of the variety you purchase.

Blends may be certified if each component variety in the blend has been certified before the blending operation. If the blend is certified, you can be certain that the proportion of each component variety in the blend will remain the same from lot to lot and from year to year.

## Germination

One of the most important qualities of seed is its ability to germinate and produce seedlings that will emerge rapidly and uniformly. But unless there is something obviously wrong with the seed — such as an excessive amount of diseased seed — you cannot judge its ability to germinate by its outward appearance. The result of the germination, or "warm," test will give you a fairly accurate indication of the percentage of seedlings that will emerge under favorable soil and weather conditions. When the soil is crusted or a long period of cold, wet weather follows planting, however, the percentage of seedlings that emerge and become established will be lower than the percentage germination. Deep planting may also result in less than desirable stand establishment. The herbicides that are commonly used to control weeds in soybeans will probably have only a minor effect on stand establishment. But it may be affected if some of the herbicides that are used on the previous corn crop carry over.

You should try to buy soybean seed that has a percentage germination in the high 80s or low 90s. In some years seed that has such a high percentage will be in short supply or may not be available at all. If wet weather, high humidity, or both occur as the seed is filling and after it matures, diseases such as pod and stem blight may attack the seed and reduce germination. Low humidity during the harvest season predisposes the seed to mechanical damage during harvest and subsequent handling. Disease and mechanical injury kill some seed and tend to reduce the vigor of the viable seed.

## Seed Vigor

The Association of Official Seed Analysts defines seed vigor as "comprising those seed properties which determine the potential for rapid uniform emergence and development of normal seedlings under both favorable and stress conditions." Because seed vigor is a difficult characteristic to measure, it is seldom stated on the label. Although several methods of testing for vigor have been developed, none has been universally accepted by seed testing laboratories.

The method most commonly used in Illinois to measure vigor is the "cold" test. The soybean seed is planted in a mixture of sand and unsterilized soil that is maintained at 50° F. for seven days. These conditions are conducive to disease, which

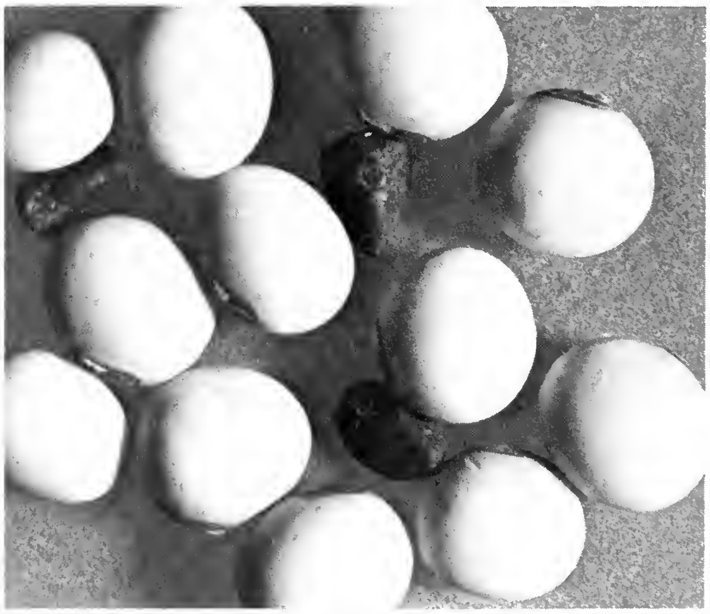
reduces stand establishment. The temperature is then increased to 78° F. and maintained at that level for four days. At the end of that time, the emerged normal seedlings are counted. The vigor of the lot of seed tested is indicated by the difference between the result of the warm test and that of the cold test. For instance, if 88 percent of the seed germinates in the warm test and 78 percent in the cold test, the seed is more vigorous than if the result of the warm test had been 88 percent and that of the cold test 68 percent. The seller of seed may or may not have cold-test information on the seed offered for sale.

## Impurities

Another quality you should consider in selecting seed is its purity, or freedom from inert matter, seed of other crops, and weed seed. Often, much of the inert matter in seed is split seed (see photograph at right, top). Splitting is particularly likely if the humidity is low during harvest. Try to obtain 98 percent pure seed that contains less than 2 percent inert matter. The percentage of pure seed in the sample is determined by subtracting from the total weight the weight of the inert matter as well as that of the seed of other crops and weed seed. Thus, if 2 percent of your seed is inert matter, the seed is not necessarily 98 percent pure. It may contain, in addition to inert matter, a certain percentage of seed of other crops, weed seed, or both.

High quality seed should be almost completely free of seed of other crops and weed seed. If the information furnished by the seller indicates that another kind of seed is present in the soybean seed, you should ask what kind it is. This information does not have to be listed on the label. In Illinois, the kind of seed that is most likely to be mixed with soybean seed is corn (see photograph at right, middle). One corn kernel per pound of soybean seed is approximately 0.05 percent by weight. In addition to seed of other crops, there may also be some seed of another soybean variety.

The weed seed most commonly found in soybeans is morningglory (see photograph at right, bottom). The kind of weed seed present does not have to be listed on the label unless the seed contains per pound of soybean seed four or more seeds or bulblets of one or more of the restricted noxious weeds (buckhorn, bullnettle, wild carrot, oxeye daisy, curled dock, dodder, wild garlic, giant foxtail, mustards, wild onion, bird rape, and quackgrass). The sale of agricultural seed containing seed of the following weeds is prohibited: field bindweed, hoary cress, johnsongrass, Russian knapweed, perennial sowthistle, leafy spurge, and Canada thistle.



Split soybean seed, top; soybean seed mixed with corn, middle; and soybean seed mixed with morningglory seed, bottom.

# Weed Control

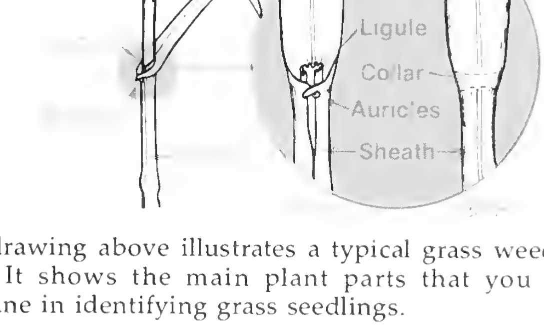
Weed control is a critical aspect of soybean production. Because weeds compete with soybeans for nutrients, water, and light, the less effectively they are controlled, the more they reduce yields. The degree to which they reduce yields depends in part upon the timeliness of your weed control measures. Competition studies indicate that to prevent significant yield reductions you must control weeds within 4 to 6 weeks after planting. Weeds that emerge after this period have little effect upon yields. However, they can diminish your profits by interfering with harvesting or causing market dockages.

## Identification

Being able to identify weeds shortly after they emerge will enable you to select the most appropriate control program. Identification of seedling broadleaf and grass weeds requires close examination of the plant, sometimes with the aid of a hand lens. Learn to recognize the distinctive vegetative characteristics of the common soybean weeds.

### Grass Weed Seedlings

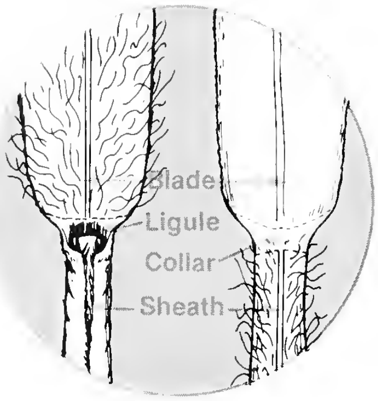
Grass seedlings are distinguished from one another by differences in their blades, sheaths, ligules, collars, and auricles. The **sheath** encloses the bud-shoot and is connected to the leaf **blade** at the **collar**, which is on the outer side of the leaf. The **ligule** is located on the inner side of the leaf blade and appears as an extension of the sheath at its intersection with the blade. The **auricles** are finger-like projections of the collar that extend around the shoot. Blades, sheaths, and collars vary among species in their hairiness, texture, and color. Ligules are hairy or membranous and vary in length. Auricles, which may or may not be present, vary in length. Long auricles may cross one another and clasp the stem in a clawlike fashion, as in quackgrass. Detailed drawings of these parts on several common grass weeds are shown on page 24.




The drawing above illustrates a typical grass weed seedling. It shows the main plant parts that you should examine in identifying grass seedlings.

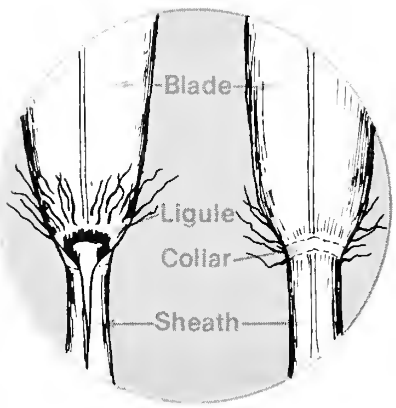
### Giant Foxtail

Leaf **sheath** is sparsely hairy, split, overlapping and has a row of hairs along the margins. Leaf **blade** is densely hairy above and sparsely hairy to smooth below. **Ligule** is a fringe of hairs. **Collar** is continuous and smooth. **Auricles** are absent.



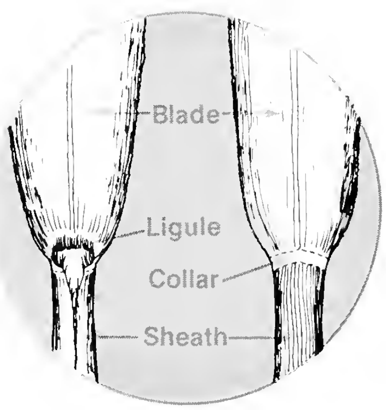

### Yellow Foxtail

Leaf **sheath** is smooth, flattened, split, and overlapping and has a reddish base near the soil surface. Leaf **blade** is smooth, except for long whitish hair on the upper surface near the ligule. **Ligule** is a fringe of hairs. **Collar** is narrow and continuous. **Auricles** are absent.



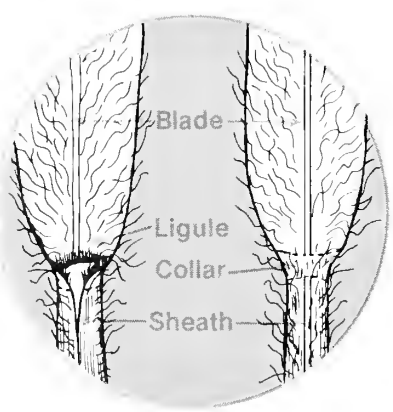

### Green Foxtail

Leaf **sheath** is smooth to sparsely hairy and has overlapping, hairy margins. Leaf **blade** is smooth and finely veined and has rough margins. **Ligule** is a fringe of hairs. **Collar** is continuous. **Auricles** are absent.




### Fall Panicum

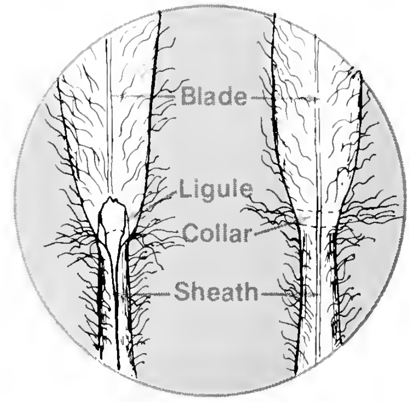
Leaf **sheath** is densely hairy and sometimes reddish near the soil surface, with split, overlapping margins. Leaf **blades** of the early seedling are densely hairy. **Ligule** is a fringe of hair. **Collar** is narrow and hairy. **Auricles** are absent. As the plant develops, sheath, blades, and collar become sparsely hairy to smooth.




Much of the information on identification of weed seedlings is adapted from Joe Paul Downs, *Weed Seedlings and Vegetative Identification*, Vocational Agriculture Service, University of Illinois at Urbana-Champaign.

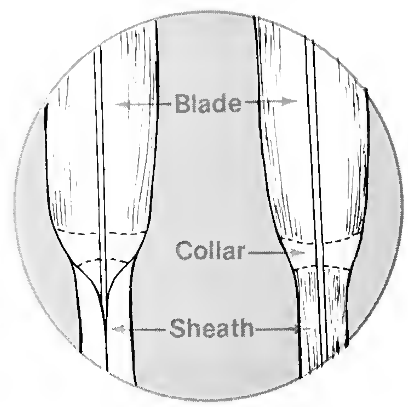
### Large Crabgrass

Leaf **sheath** is very hairy, split, and overlapping. Leaf **blade** is broad, pointed, and hairy above and below. **Ligule** is medium to long and membranous, with a jagged margin. **Collar** is broad, divided by a midvein, and has hairy margins. **Auricles** are absent.



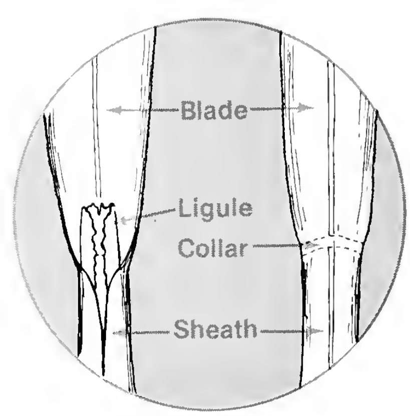

### Barnyardgrass

Leaves are rolled in a slightly flattened budshoot. Leaf **sheath** is smooth, split, overlapping, and slightly flattened, with membranous margins. Leaf **blade** is smooth and slightly keeled (resembling the keel of a boat) below. **Ligule** is absent. **Collar** is broad and divided by a midvein. **Auricles** are absent.



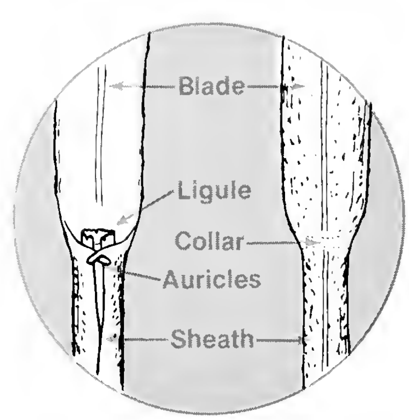

### Johnsongrass

Leaf **sheath** is smooth and has a reddish tint near the soil surface. Leaf **blade** is smooth and flat and has rough margins. **Ligule** is long and membranous, with a jagged margin. **Collar** is continuous and finely veined. **Auricles** are absent. Johnsongrass is difficult to distinguish from shattercane.



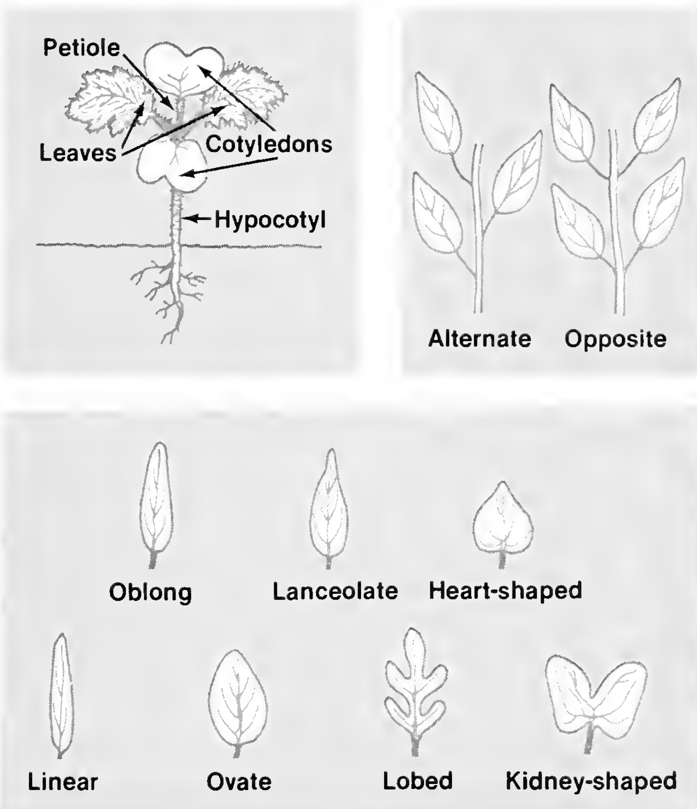

### Quackgrass

Leaf **sheath** is split, has overlapping margins, and may have sparse, short hairs. Leaf **blade** is rough above and has sparse, short hairs beneath. **Ligule** is short and membranous, with a jagged margin. **Collar** is narrow and continuous. **Auricles** are slender and clasp the stem in a clawlike fashion.



## Broadleaf Weed Seedlings

Distinctions among broadleaf weed seedlings are much easier to discern. The seedlings vary in the shape, color, texture, and arrangement of the main plant parts: the hypocotyl, cotyledons, true leaves, and petioles. The **cotyledons** are the first pair of leaves on the broadleaf seedlings. The portion of the stem between the cotyledons and the roots is the **hypocotyl.** All leaves produced after the cotyledons are **true leaves.** The stalk by which a leaf is attached to the stem is a **petiole.** The accompanying illustrations show these features on some common broadleaf weed seedlings.




These drawings show the main parts of a typical broadleaf weed seedling, the two leaf arrangements, and several common leaf shapes.

### Common Cocklebur

**Hypocotyl** is smooth, purple at the base, and green above. **Cotyledons** are smooth, fleshy, waxy, oblong, and narrow at the base, where they join the stem. **True leaves** are rough and ovate, with rounded tips and toothed margins. Leaves are first opposite and later become alternate. **Petioles** are long, purplish, and sparsely hairy.

### Velvetleaf

**Hypocotyl** is covered with short, soft hairs. **Cotyledons** are ovate to heart-shaped and have rounded apexes, entire margins (having no indentations), and sparsely hairy surfaces. **True leaves** are ovate to heart-shaped, with round to acute apexes, serrated (saw-toothed) margins, and soft, hairy surfaces. **Petioles** are round and covered with soft, short hairs.

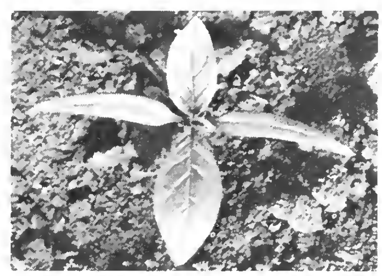
### Pennsylvania Smartweed

**Hypocotyl** is reddish and smooth. **Cotyledons** are lanceolate to ovate, smooth, and fleshy and have a pointed tip. **True leaves** are ovate to oval and sparsely hairy, with purplish patches and veins. Leaves are alternate and have a papery sheath (ochrea) at the base of the petioles, with small hairlike projections along the upper edge. **Petioles** and stems are tinged red.

### Redroot Pigweed

Seedlings have a shallow, red taproot. **Hypocotyl** is short and reddish to purple. **Cotyledons** are oblong to lanceolate and have reddish midveins and undersides. **True leaves** are alternate and ovate to oval, with notched tips and purple to pinkish midveins and undersides. Leaf margins may have hairlike projections. **Petioles** are pink and are covered with rough hairlike projections.

### Jimsonweed



**Hypocotyl** is fleshy, purple-tinged, and smooth to sparsely hairy. **Cotyledons** are smooth, waxy, and lanceolate, with purple-tinged, sparsely hairy to rough veins. **True leaves** are alternate, large, smooth, and ovate. They have pointed apexes and irregularly toothed margins. **Petioles** are long and pale green to purple and may have sparse, short hairs.

### Tall Morningglory

**Hypocotyl** is tall, reddish to purple, and smooth to rough. **Cotyledons** are smooth and kidney-shaped. **True leaves** are large, oval, and heart-shaped, with a hairy surface. **Petioles** are long and smooth to hairy. The stem is twining and vinelike.

### Ivyleaf Morningglory

**Hypocotyl** is reddish and hairy. **Cotyledons** are shiny, smooth, and oval. They have deeply indented bases and apexes, which make them kidney-shaped. **True leaves** are very hairy, three-lobed, and ivy-shaped. **Petioles** are long, reddish, and hairy. The stems have a vinelike growth habit.

### Giant Ragweed

**Hypocotyl** is shiny and green, and purple at the base. **True leaves** are opposite, rough, hairy, and usually deeply lobed, with long **petioles.** Leaves may have three or five lanceolate, serrated (saw-toothed) lobes.

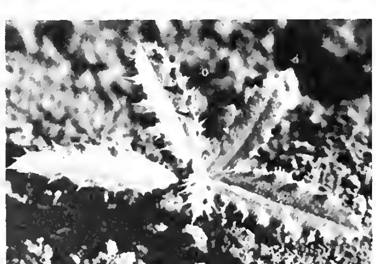
### Hemp Dogbane

**True leaves** are opposite and smooth, with some hair on the lower surface. Leaves are ovate to lanceolate and have a blunt apex. **Petioles** are very short or may be absent. Hemp dogbane is often mistaken for common milkweed, but does not have its milky sap.

### Common Milkweed

**Hypocotyl** is smooth and medium to light green. **Cotyledons** and **true leaves** are oblong, oval, and thick. The true leaves are also opposite and have a waxy appearance, prominent, whitish midveins, and pointed tips. **Petioles** and stems may be rough or have short hairs. Veins or stems exude a milky sap when bruised. When the plant emerges from overwintering rootstocks rather than from seed, a fairly common occurrence, it lacks the hypocotyl and cotyledons.

### Canada Thistle



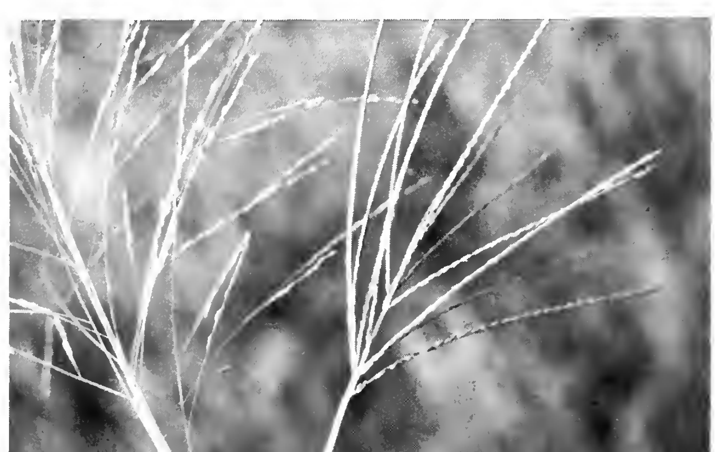
**Hypocotyl** is pale green. **Cotyledons** are thick and dull, with a shiny midvein on the undersurface. The hypocotyl and cotyledons are absent when, as commonly occurs, the plant emerges from creeping rootstock rather than from seed. **True leaves** are waxy and oblong to lance-shaped. Leaf margins vary from irregular and deeply cut or spiny toothed to almost smooth, with few or no spines.

## Mature Weeds

Once weeds reach maturity, attempting to control them with herbicides is usually impractical unless the weeds must be desiccated to aid harvesting. You should not disregard mature weeds, however, because they reinfest your fields with seed and the perennials reproduce vegetatively. Note which species are infesting your fields and choose chemical and mechanical treatments the following year that will control those species. The seedheads of several common grasses and yellow nutsedge are illustrated below and on page 27. *Weeds of the North Central States,* Bulletin 772, illustrates the mature stage of most weeds found in Illinois. That publication is available from your county Extension adviser.

In assessing weed problems, keep in mind that the most numerous weeds, such as giant foxtail, may not necessarily be the most difficult to control. The weeds that are most difficult to control in soybeans with preplant or preemergence herbicides are morningglory and cocklebur. Grasses are difficult to control with most current postemergence herbicides. More effective postemergence herbicides for grass control will be available in the near future.

**Giant, Green, and Yellow Foxtail,** left to right



**Fall Panicum, left, and Large Crabgrass**

Barnyardgrass

Shattercane

Johnsongrass

Yellow Nutsedge

## Mechanical Control

A good approach to weed control in soybeans is usually to combine cultural practices with mechanical and chemical weed control measures. These are some cultural practices that promote good soybean growth and help soybeans compete with weeds: proper selection of planting date, rate, and depth as well as row width; use of weed-free, high quality seed of adapted varieties; proper liming and soil fertility; and crop rotation.

The most commonly used mechanical weed control practices are rotary hoeing and row cultivation. The former is particularly effective in controlling early weeds. It usually produces the best results when performed just about the time weeds are emerging (in the "white" stage) through slightly crusted soil, but it is also effective in slightly damp or loose soils. Rotary hoeing aids soybean emergence by breaking crusted soil. If you also apply preemergence or preplant herbicides to control early weeds, you need not delay rotary hoeing to allow the herbicides to work. Rotary hoeing will lightly incorporate herbicides and help control early weeds.

You can use the rotary hoe until soybeans are 4 inches tall. Be particularly careful if you rotary hoe when soybeans are at the "crook" stage because they are quite turgid at that time and highly susceptible to injury. If you rotary hoe when soybeans are larger than the first trifoliate stage, you should probably wait until the hottest part of the day when soybeans are limp and less subject to injury. Operate the rotary hoe at 6 to 8 miles per hour, and weight it enough to stir the soil. Currently, farmers in Illinois rotary hoe one or two times during the growing season.

The primary purpose of row cultivation is to control weeds between the row. It may also throw soil onto and smother small weeds in the row. You will get the best results if cultivation is shallow and the weeds are small. If you cultivate later, be sure to make adjustments to avoid injuring soybean roots, and minimize ridging because it interferes with harvesting.

Illinois farmers usually cultivate one to three times during the growing season. Under certain circumstances, however, it may not be possible or necessary to cultivate. For example, if you are growing soybeans in narrow rows, you may not be able to cultivate unless you plant in a skip-row pattern to leave room for the tractor tires (see page 18 for an illustration of this practice). If you can control weeds adequately with cultural practices, rotary hoeing, and herbicides, you may not need to cultivate soybeans unless the soil is crusted enough to prevent proper aeration and water uptake.

# Chemical Control

Herbicides can be divided into three categories: preplant, preemergence, and postemergence. Preplant and preemergence herbicides, which are applied to the soil, are used on almost all the soybean acreage in Illinois (the former on about 70 percent, the latter on about 25 percent). Postemergence herbicides, which are applied to the foliage of weeds, are now used on 10 to 15 percent of the state's soybean acreage. Use of these herbicides is rapidly increasing.

Farmers often use combinations of herbicides applied either together in tank mixes or separately at different times. In fact, about 90 percent of the soybean acreage in Illinois receives combinations of two or more herbicides. Tank mix combinations can help you accomplish two purposes. First, by combining a grass herbicide with a broadleaf weed herbicide, you can control a broad spectrum of weeds. And, second, by combining certain broadleaf herbicides at rates lower than those at which the herbicides would be applied alone, you can minimize injury to soybeans.

## Preplant Herbicides

Since preplant herbicides are applied within a few weeks before planting, there is no risk of mechanical injury to the crop seed during application and incorporation. To minimize crop injury, poor weed control, and carryover, be sure to distribute preplant herbicides uniformly. They are incorporated to reduce herbicide loss caused by vaporization and photodecomposition or to make the effectiveness of the application less dependent upon rainfall. Try to place most of the herbicide in the top 1 or 2 inches of soil since that is where most annual weed seeds germinate.

The depth and thoroughness of incorporation depend upon the type of equipment you use, the depth and speed at which you operate it, the texture of the soil, and the amount of moisture in it. The implements most commonly used to incorporate herbicides are the tandem disk and field cultivator. With either implement you should make two passes for optimum incorporation of the herbicide. Make the second pass at some angle to the first.

If you incorporate with the tandem disk, use blades that are less than 22 inches in diameter and spaced less than 8 inches apart. Maintain a speed of 4 to 6 miles per hour. Since most of the herbicide will be distributed at one-half to two-thirds of the cutting depth, set the disk to cut 3 to 5 inches deep, so that the herbicide will be incorporated at the proper depth.

If you incorporate with a field cultivator, it should have three or more rows of shanks having shovels that are at least as wide as the lateral spacing between the shanks in all the rows. Set the cultivator so that it is level and will cut 3 to 4 inches deep. Maintain a minimum speed of 5 to 6 miles per hour. Mount a drag harrow behind the cultivator to level the ridges and mix the soil lightly. For more specific instructions on incorporation, be sure to read the herbicide label.

## Preemergence Herbicides

Preemergence herbicides should be applied to the soil surface at planting or within a few days after planting. Some of these herbicides, if they are applied after the soybeans have begun to emerge, may cause significant soybean injury. Others can safely be applied through the soybean emergence or "cracking" stage. By delaying the herbicide application, you may be able to increase the effectiveness of some herbicides in controlling broadleaf weeds, but at the same time you will diminish their effectiveness against grasses. To be fully effective, preemergence herbicides require ½ to 1 inch of rain within 7 to 10 days after planting. The rainfall provides moisture needed for herbicide uptake, and moves the herbicide down into the soil where weed seeds are germinating.

## Postemergence Herbicides

Postemergence herbicides are currently used primarily to control broadleaf weeds. Several selective postemergence herbicides for grass control are now being developed and may soon be available. Postemergence herbicides should be applied when the weeds are small, but actively growing, and when the soybeans are large enough to recover from early injury caused by contact with some herbicides.

If the weeds are somewhat taller than the soybeans, you may be able to avoid soybean injury by making an over-the-top directed application with a recirculating sprayer or wick-type applicator, which places the herbicide on the weeds while keeping it off the soybean plants. These applicators are particularly useful for treating weeds such as shattercane, johnsongrass, volunteer corn, and sunflower, which are often taller than soybeans.

If the weeds are smaller than the soybeans, you can direct the sprays under the soybeans by means of special equipment that will precisely maintain the spray pattern at the base of the soybean plant. The basal method is most effective for control of late-emerging weeds such as morningglory, wild cucumber, prickly sida, and possibly cocklebur.

| | Preplant incorporated | Preemergence | Postemergence | Postemergence directed: Basal | Postemergence directed: Over-the-top |
|---|---|---|---|---|---|
| **Grass weeds** | | | | | |
| Foxtail | G* | G | F-G | F | . . . |
| Shattercane | G | F | F-G | . . . | G |
| Volunteer corn | F | P | F-G | . . . | G |
| Yellow nutsedge | G | F | F-G | F | P |
| Johnsongrass | F | P | F-G | P | G |
| **Broadleaf weeds** | | | | | |
| Pigweed | G | G | F | F | P |
| Giant ragweed | P | P-F | F | F | P-F |
| Smartweed | G | G | G | F | P |
| Velvetleaf | F-G | F-G | F-G | F | P-F |
| Jimsonweed | F | F | G | F | F |
| Cocklebur | F | F | G | F | P |
| Morningglory | P | P | F | G | P |
| Canada thistle | P | P | F | P | P |
| Common milkweed | P | P | P | P | F |

*G = good, F = fair or variable, and P = poor.

| Grass weed control | | | | Broadleaf weed control | | | |
|---|---|---|---|---|---|---|---|
| PPI* | PPI or PRE | Post | Post directed | PPI or PRE | PRE only | Early post | Post directed |
| Basalin | Lasso | Hoelon | Roundup† | Amiben | Lorox | Basagran | Lorox |
| Treflan | Dual | Poast | Paraquat | Lexone | Goal | Dyanap | Sencor |
| Vernam | Prowl | | | Modown | | Butoxone | Butoxone |
| | Surflan (Pre only) | | | Sencor | | Premerge-3 | Butyrac |
| | | | | | | Blazer | |

* PPI = preplant incorporated, Pre = preemergence, Post = postemergence.
† Over-the-top.

## Choosing a Herbicide

The kind of herbicide you need depends upon your weed problem, soil conditions, and preference as to the time of the application. First, identify the weeds that are causing problems. Then, to determine the herbicides that are most likely to help you control those weeds, refer to the herbicide selection chart on the back of the current issue of the *Row Crop Weed Control Guide* (this publication is printed both separately and as a part of the *Illinois Agronomy Handbook;* both are available from your county Extension adviser), or refer to the tables above. The table at the top of the page shows the relative effectiveness with which herbicides control weeds, and the one below it lists herbicides that are commonly used for soybeans.

In deciding which of these herbicides to use, give careful consideration to soil conditions. The texture of the soil, its organic matter content, and the amount of crop residue left on it influence the effectiveness of soil-applied herbicides (see pages 4 to 5 for a discussion of tillage systems and their effects on crop residue and weed control). Some herbicides perform better on silty clay loam that contains 3 to 6 percent organic matter. Others are more effective on silt loam soils that contain 1 to 3 percent organic matter. Some herbicides cannot be used on sandy soils that contain very little organic matter. For most soil-applied herbicides, the recommended rate has been adjusted to take into account these soil differences.

## Herbicide Injury

Some soybean herbicides may injure seedling soybean plants. The initial effects of this injury, however, are often outweighed by the increased weed control herbicides provide. Usually, the injury has little or no effect on yield unless the plants are under additional stress such as that from poor growing conditions and disease.

This section describes the symptoms of injury from some commonly used herbicides (for color illustrations of the symptoms, see pages 45 to 46). You can minimize injury by applying herbicides accurately and uniformly at the recommended rate. Be sure to follow the directions and observe the precautions on the label.

## *Soil Application*

The **dinitroaniline herbicides** (DNAs) — Basalin, Prowl, Surflan, and Treflan — may injure soybeans if applied at excessive rates. The symptoms of injury are delayed emergence, poor lateral root formation, and swelling and cracking of the hypocotyl. The plants may be stunted and have crinkled leaves. DNA injury is rarely severe enough to reduce soybean yield. Surface applications of Prowl or Surflan may cause a stem callus to form at the soil surface. This weakens the stem and may cause it to lodge or break.

The **acetanilides,** Lasso and Dual, may produce a slight crinkling of the first few leaves. The leaflet midvein may be shortened, making the leaflet heart-shaped or giving it a "drawstring" appearance. The injury is not likely to result in yield reduction.

**Vernam** may delay emergence and the unfolding of unifoliate and early trifoliate leaves. Cotyledons may be thick and waxy. Leaves may be crinkled and have irregular margins. Plants will usually outgrow this injury without suffering yield reduction. More severe injury, evidenced by shortened internodes and leaflets sealed together, can result in stand reduction.

The **triazine herbicides** that can injure soybeans are metribuzin (Sencor or Lexone), which is a soybean herbicide, and atrazine and simazine, which are corn herbicides. The symptoms of injury from these two herbicides are similar and may be compounded if metribuzin is applied to a field where atrazine or simazine has carried over from the previous season's corn crop. The plants emerge normally but soon exhibit interveinal and marginal chlorosis (yellowing), beginning with the oldest leaves. Chlorosis may be followed by necrosis, which is death of the tissue (indicated by browning). Plants treated with metribuzin may show some bronzing before becoming necrotic. Driving rains soon after application may splash metribuzin onto soybean foliage and cause partial leaf burn. To minimize triazine injury, apply the lowest rates that will still give good weed control. Be particularly careful when applying metribuzin, especially on fields that were previously treated with atrazine. On soils with relatively high pH, you may want to apply some other suitable herbicide.

**Lorox** injury symptoms are similar to those produced by the triazines. Lorox may be splashed by raindrops from the soil onto the leaves and produce partial leaf burn. Lorox injury seldom reduces yield.

**Modown** and **Goal** may stunt growth and produce crooked roots. The unifoliate and several trifoliate leaves may be crinkled and necrotic. The crinkling is usually more extreme than that produced by other herbicides. The center leaflet of the trifoliate leaf may be underdeveloped or missing. Yield may be affected by this injury.

**Amiben** seldom injures soybeans unless it is applied at high rates or heavy rain occurs soon after planting. The principal symptom of injury is proliferated and abnormal roots. Injured plants may appear slightly stunted and have smaller leaves than untreated plants.

## *Foliar Application*

**Basagran** injury appears as leaf yellowing, bronzing, speckling, or burn. The injury is usually temporary, and yield is not generally affected. The use of crop oil may increase the injury, but it also increases weed control.

**Dyanap** or **Premerge-3** can produce necrotic spots on the foliage. Dyanap may cause some stunting and stand reduction, especially if applied to the growing point soon after the first true leaves unfold. To avoid injury that might reduce yield, you should time the Dyanap treatment carefully, and be sure to use the appropriate application technique. Follow the label recommendations.

**Blazer** injury causes necrotic spotting of leaf tissue that comes in contact with the spray and occasionally causes leaf crinkling. Severe injury by Blazer can reduce yields if it is applied late.

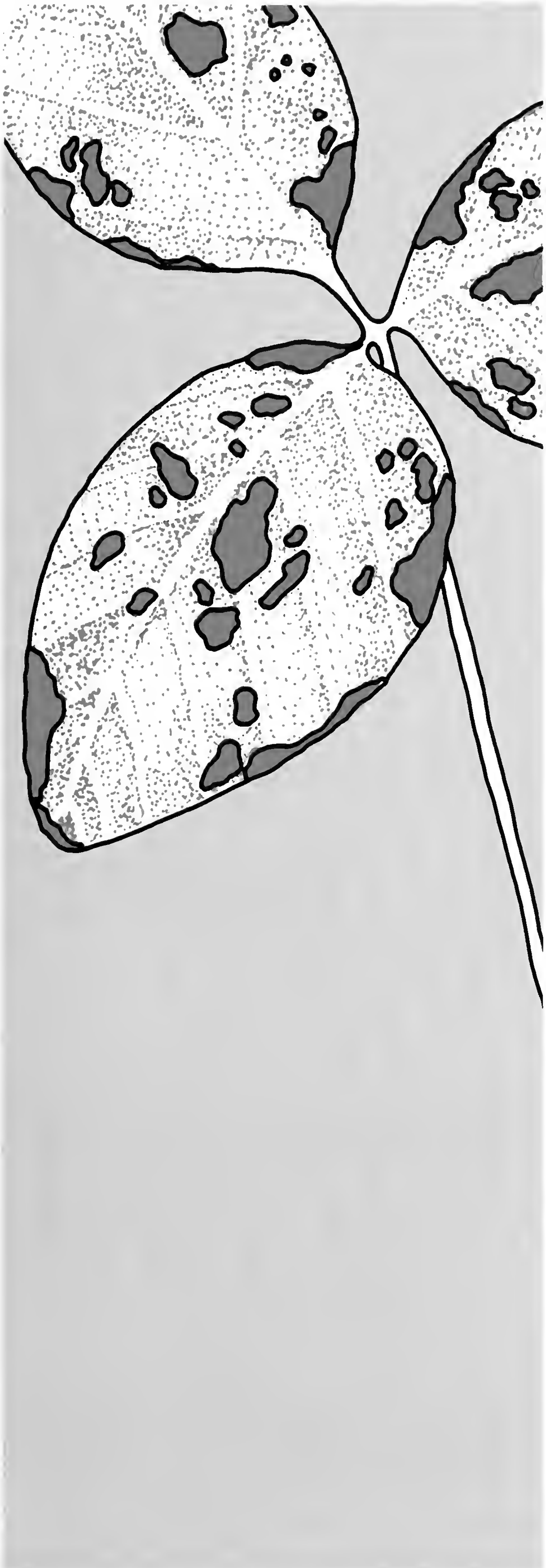
**2,4-DB** (Butyrac or Butoxone) injury may result in wilting plants with curved, cracked stems and proliferated growth protruding from these cracks. The weakened stems may lodge. You can minimize injury by making a directed application to keep the herbicide off the soybean foliage.

## *Drift From Adjacent Areas*

**2,4-D,** which is closely related to 2,4-DB, may drift into soybean fields from adjacent, treated corn fields or other areas. Injured soybean plants may exhibit twisting and bending of stems, callus formation, parallel veination, and puckered leaves with edges cupping downward. The leaves may be abnormally narrow.

**Banvel** drift from adjacent areas also produces abnormal plants. Leaves may be puckered or crinkled, and the leaf margins may be rolled up, producing a cupping effect. Leaf buds may not unfold normally, giving the field a yellowish cast.

Use extreme caution when applying 2,4-D or Banvel near soybeans. Try to apply these and other herbicides on cool days and when there is little wind. But keep in mind that although this precaution may reduce problems with herbicide injury it will not necessarily eliminate them.



# Plant Diseases

Plant diseases annually reduce soybean yields in Illinois by 10 to 30 percent. Approximately 25 diseases are responsible for these yield losses. The primary causal agents (pathogens) of these diseases are fungi, bacteria, viruses, and nematodes.

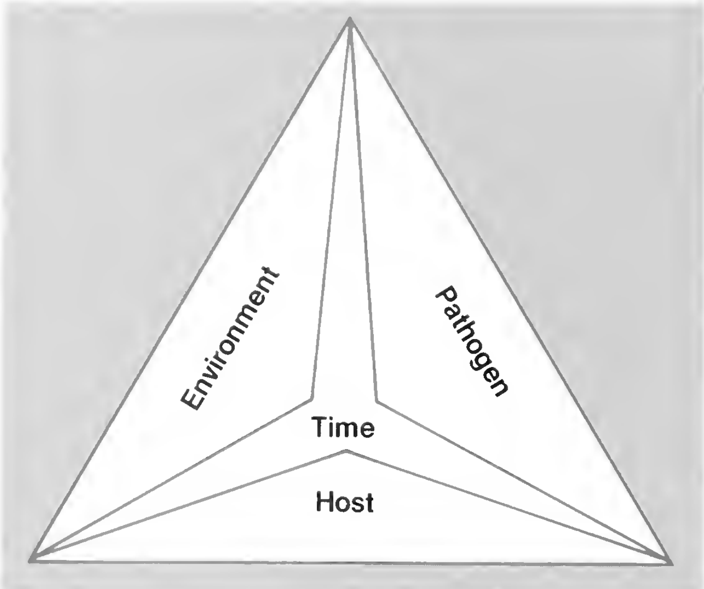
Four conditions are necessary for disease to develop: (1) a susceptible host plant, (2) a sufficient quantity of a virulent pathogen that is capable of rapid reproduction and spread, (3) an environment that is favorable to the pathogen, and (4) enough time for the disease to develop. The interaction of these conditions is illustrated in the diagram on page 32. Narrow row spacing, continuous soybean production, reduced tillage, irrigation, and warm, wet weather may increase the likelihood that disease will become a serious problem in your soybean fields.

## Integrated Control

The aim of an integrated disease control program is to disrupt the conditions that are necessary for development of diseases. To plan an effective program, you must know the pathogens that cause the common soybean diseases, the plant parts those pathogens attack, the timing of the attack, the disease cycles, and the means by which disease-causing organisms spread and reproduce. It is also important to know which diseases are likely to occur in your area of the state and how serious they can become. The maps on page 33 show the regions of Illinois where the risk of yield loss from certain diseases is greatest.

Field surveys are another means of anticipating disease problems. If a survey shows that a disease is present in your fields one year, you will have some advance warning that it may pose a more serious problem in future years. You can then plan to take measures to prevent a serious outbreak of disease.

Although you can sometimes control diseases through a single practice, long-term reduction of the problem usually requires several control measures. These include selecting resistant varieties; rotating crops; practicing clean tillage; planting disease-free, high quality seed; maintaining soil fertility; controlling nematodes, insects, and weeds; and applying fungicides.




## Disease-Resistant Varieties

The most economical and efficient method of controlling disease is to plant resistant varieties. For a listing of public varieties that have resistance to one or more common diseases, obtain a copy of *Report on Plant Diseases* No. 507 from your county Extension adviser. This listing is updated annually. Check with seed companies for information on the resistance of private varieties.

An important point to keep in mind if you plan to use this control method is that varieties are resistant only to particular races of a pathogen. In Illinois, there are races of the causal agents of Phytophthora root rot and soybean cyst nematode that attack the commonly grown resistant varieties. If you observe any signs that the disease resistance of a variety is breaking down, be sure to alert your county Extension adviser or seed producer.

## Crop Rotation and Clean Tillage

Because resistance to many major diseases of soybeans is not available, it is important to use crop rotation and residue-destroying tillage. With these methods, you can control pod and stem blight, anthracnose, stem canker, Alternaria leaf spot, Phyllosticta leaf spot, powdery mildew, bacterial blight, purple seed stain, and several other fungal and bacterial leaf diseases.

Rotation controls disease effectively because few of the fungi and bacteria that attack soybeans infect other crops. By rotating with corn, small grains, or forages, you deprive soybean pathogens of a host on which to feed, reproduce, and carry over between soybean crops. Destruction of infected crop debris is also a good way of preventing pathogens from carrying over to the next soybean crop. If you use conservation tillage, soybean debris will not decompose as rapidly as when conventional tillage is used. As a result, diseases that are normally minor can build up and cause severe yield losses. If you have a serious problem with soil erosion and are using conservation tillage to control it, rely on crop rotation and other methods to control plant diseases.

## High Quality Seed

Plump seed that is free of disease-carrying organisms and cracks will produce vigorous stands and sustain fewer losses from disease. Many important pathogens can infect soybean seed. Infection often reduces the quality of seed, lowering its germination, vigor, and yield. The disease that affects soybean seed quality most severely is pod and stem blight. Seed rotting and seedling blight fungi may also cause severe problems if you plant diseased or cracked seed or seed that has low vigor.

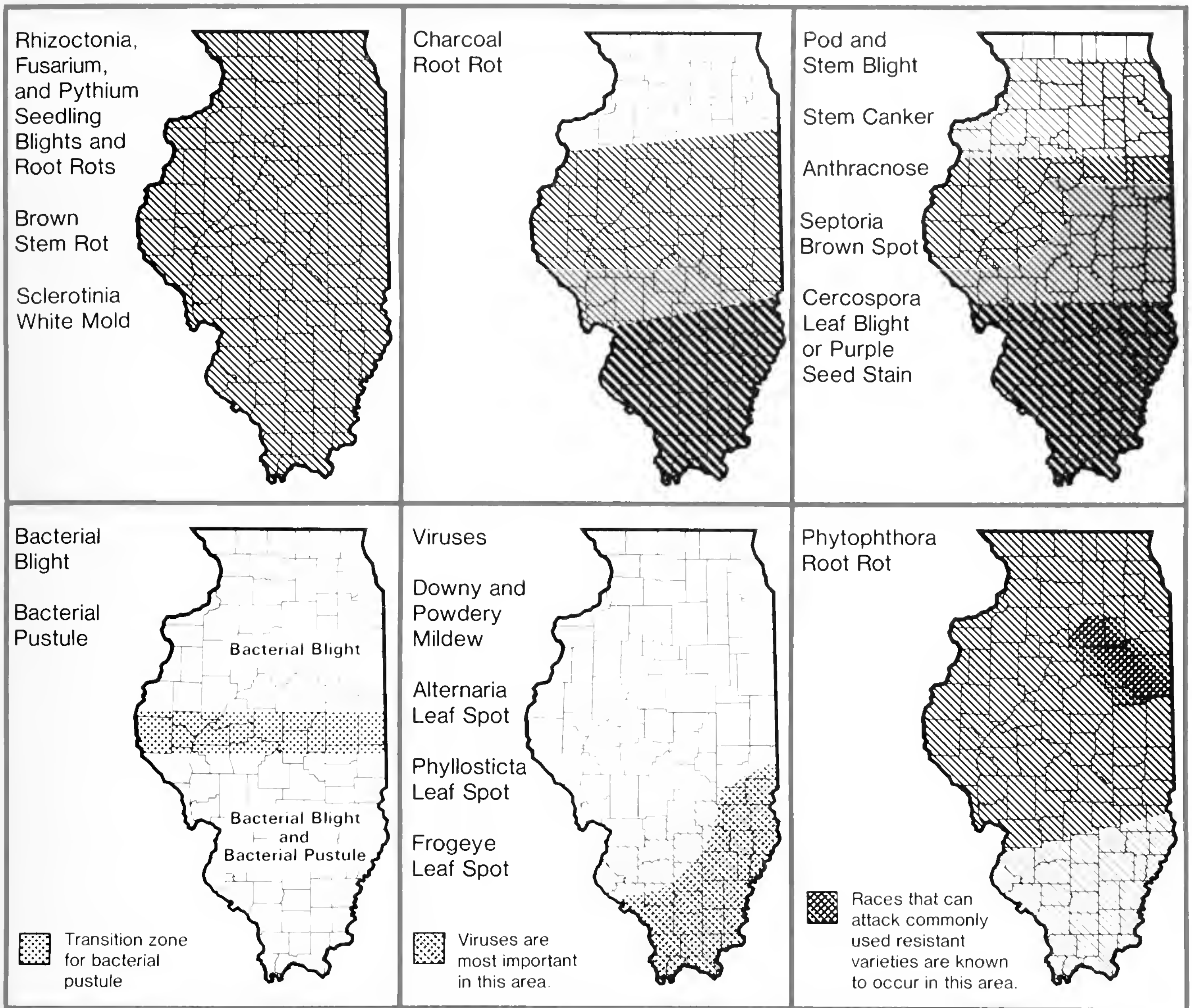
To reduce yield loss from these diseases, try to obtain seed that germinates 80 to 85 percent in a cold germination test, which is a better indicator of seed quality than the standard warm germination test.

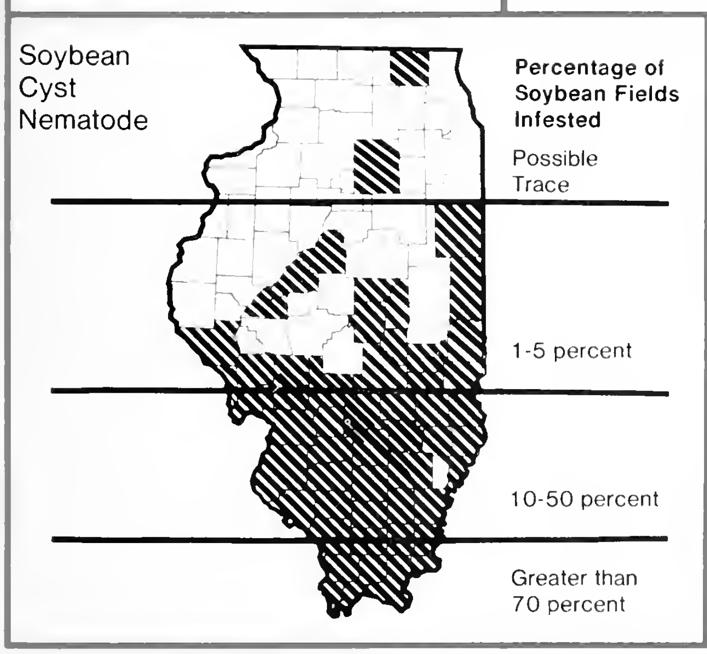
It is usually not worthwhile to try to increase the germination of poor quality seed with a fungicidal seed treatment. Poor quality seed, even if properly treated, does not produce stands equal to those from untreated, high quality seed. The best way to obtain good stands of vigorous seedlings is to plant high quality seed in a warm (60° F. or higher), moist, well-drained seedbed at the proper depth and spacing.

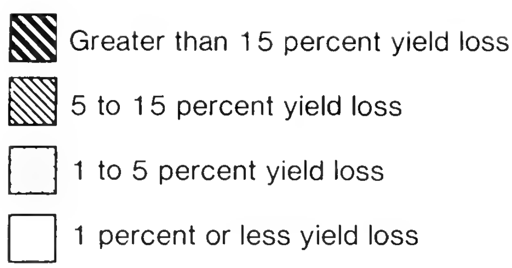
High quality seed produced in fields where there is low incidence of disease should be harvested as soon as the seed is mature. The seed should be handled with great care to prevent mechanical damage. Many seed-rotting fungi that live in the soil can enter the seed through cracks caused by rough handling. To reduce cracking and splitting, adjust the combine speed and cylinder carefully (for more detailed instructions on combine adjustment, see page 56), and harvest seed fields when the moisture content of the soybeans is 12 percent or higher. Handling seed that has a moisture content of less than 9 or 10 percent is not recommended because it greatly increases cracking and splitting.

## Fertility

Maintaining adequate, balanced soil fertility can help reduce yield loss from diseases. Healthy, vigorous plants are more tolerant of pathogens and better able to produce a near-normal yield even when diseases are present. Inadequate levels of phosphorus or potash can increase losses from charcoal rot, several other root rots, nematodes, stem canker, and pod and stem blight.




**Potential Yield Loss from Plant Diseases in Illinois Soybean Production**

These maps show the percentage soybean yield loss that can be caused by common plant diseases in particular parts of Illinois if susceptible varieties are grown. Losses may be higher or lower in particular fields but will rarely exceed 20 to 30 percent, regardless of the weather or the number of diseases present. The risk of loss is greatest in fields that are irrigated or located in river bottoms or other areas where warm, wet conditions prevail; in fields planted to narrow rows where reduced tillage is practiced; and in fields where poor quality seed is used or where soybeans are grown continuously.

| Conditions | Point value* |
|---|---|
| Rainfall, dew, and humidity up to early bloom and pod set are: | |
| Below normal | 0 |
| Normal | 2 |
| Above normal | 4 |
| Soybeans were grown in the field last year | 2 to 3 |
| A chisel plow, disk, or no-till system is being used | 1 |
| Pycnidia (black specks) are visible on fallen petioles, and Septoria brown spot is obvious on the lower leaves | 2 |
| An early maturing rather than full-season variety is grown | 1 to 2 |
| Soybeans are to be used or sold for seed | 3 |
| Yield potential is greater than 35 bushels per acre | 2 |
| Germination of the seed at planting time is less than 85 percent in a warm test | 1 |
| Greater than normal rainfall is forecast for the next 30 days | 1 to 3 |
| The field has a history of plant disease problems | 1 to 3 |

* If the total point value equals 12 or more for seed production fields or 15 or more for grain production, fungicide application will probably increase soybean yield and quality.

## Fungicides

Fungicides can either be used as seed treatments or foliar applied. Fungicidal seed treatments control seed rots and damping-off (seedling blights). As mentioned previously, these treatments will not increase the yield of poor quality seed. You might consider seed treatment if the seeding rate is reduced, high quality seed is in short supply, or if germination is delayed because of cold, wet soil or dry soil. But even under these conditions seed treatment will help only where poor quality is caused by fungal infections. Poor germination that results from mechanical injury will not be improved by seed treatment.

Foliar fungicides can be applied to reduce losses from Septoria brown spot, Cercospora leaf blight and purple seed stain, anthracnose, pod and stem blight, and stem canker. Whether you apply a fungicide depends upon the weather and the expected severity of the disease. The six diseases listed above are most damaging when warm (70° to 80° F.), wet weather prevails from early pod fill to soybean maturity. If warm, wet weather is expected to prevail for 30 days following bloom, those diseases will be active, and fungicide spraying will be beneficial.

Two sprayings are recommended — one early in pod development (lower pods ½ to ¾ inch long) and a second 14 to 21 days later. The need for a second application depends upon the weather. If it has been dry since you made the first application and continued dry weather is forecast, the second application is unnecessary. Spray a second time if the weather has been warm and wet.

If you have grown soybeans for two or more consecutive years, the potential for a severe disease outbreak is higher than if you rotated soybeans with other crops. The potential for disease problems will also be higher if undecomposed residue from previous soybean crops is left on the soil surface. A good indication that there may be a severe outbreak of pod and stem blight is the presence of pycnidia (black specks) on fallen petioles at first bloom. If you plant early maturing varieties, you can expect greater yield loss from plant diseases than if you plant full-season varieties.

Two other considerations that should enter into your decision are the intended use of the crop and the prospects for high soybean yields and prices. Applications of a fungicide to diseased seed production fields could substantially improve seed quality. Spraying may also be economical if you anticipate high prices and yields of 40 bushels per acre or more. In making a decision about fungicide application, refer to the list of conditions above.

# Common Soybean Diseases in Illinois

The general information in the preceding section will help you anticipate disease problems and develop an integrated plan to control them. This section concentrates on the particular diseases that are common in Illinois. It describes the symptoms, explains how the pathogen survives between crops and spreads, lists the conditions that favor infection and disease development, and suggests specific control measures (for color illustrations of disease symptoms, see pages 47 to 48).

## Planting to Bloom

### • *Seed Decay and Seedling Blights or Rots*

**Symptoms.** Plants fail to emerge, resulting in a thin stand. Germinating seeds may rot in the ground, and seedlings may turn yellow and die just after emergence. Marginally affected plants often appear stunted and have low vigor. If you remove infected seed or seedlings from the soil, you will see obvious rotting of the cotyledon, root, or hypocotyl. Depending on the amount of moisture in the soil and the organism involved, this rot may be dry or soft and watersoaked. *Pythium,* for example, results in a soft, watery rot.
**Conditions.** Pathogenic fungi are commonly the causal agents of these diseases. The fungi may be either soilborne or seedborne. The soilborne pathogens are common in all agricultural soils and attack a wide variety of plants. Development of these diseases is favored by cold, wet soil or dry soil, deep planting, herbicide injury, or other conditions that slow seedling growth.
**Control measures.** You can control seed rot and seedling blight by planting high quality, disease-free seed that has a high vigor rating. Plant in a warm (60° to 70° F.), well-prepared seedbed. Avoid deep planting. Fungicide seed treatments will provide good control. Use them if you anticipate conditions that do not favor rapid germination and seedling growth, if you seed at a low rate, or if, because of fungal infection, you must use seed of marginal quality.

### • *Phytophthora Root and Stem Rot*

**Symptoms.** Early infection of plants can cause preemergence or postemergence seedling blight. Older plants develop a dull, dark brown root rot and a basal canker that may extend up the plant into the lower branches, causing the plants to wilt and die. The cortex of rotted roots can easily be peeled away, exposing the vascular system.
**Conditions.** The causal fungus survives in the soil as resting spores (oospores) for several years. These oospores are spread by farm implements, wind, or anything else that moves soil. Infection and disease development are favored by wet soil.
**Control measures.** Planting resistant or tolerant varieties is the only effective means of control. Keep in mind that the fungus is subdivided into a number of races. Races 1 and 2 are the most common in Illinois, although races 3, 4, 6, 7, 8, and 9 have been identified in the state. A total of 20 races have been identified in other states. Where varieties resistant to races 1 and 2 have been attacked, grow multiple-race resistant varieties. Although tolerant varieties are tolerant to all races, they may suffer some yield loss under severe disease pressure. New systemic fungicide seed or soil treatments may help control the disease. Since the disease is most prevalent in low areas, you can reduce incidence of the disease by improving soil drainage. A lengthy crop rotation sequence is only slightly effective because of the oospores' prolonged survival period.

### • *Rhizoctonia Root and Stem Rot*

**Symptoms.** Brick red to reddish brown cankers develop on the roots, hypocotyl, and stem below ground, causing a dry rot. Young plants may wilt and die within an area 4 to 10 feet wide.
**Conditions.** Cool, wet weather in late spring and low phosphorus and potassium fertility favor development of the disease. Unlike Phytophthora root and stem rot, this disease is not associated with low wet areas, but occurs in drier areas of the field. The fungus that causes the disease is found in practically all soils, attacks most plants, and can survive in the soil and crop debris as sclerotia for a number of years.
**Control measures.** Use the control measures recommended for seedling blights, and make sure adequate levels of phosphorus and potash are available to the crop. If Rhizoctonia cankers develop, cultivate soil into the row to help secondary roots develop above the canker, allowing the infected plants to recover.

### • *Fusarium Root Rot*

**Symptoms.** The symptoms are similar to those of Rhizoctonia except that the taproot shows a brownish decay.
**Conditions.** Same as for Rhizoctonia.
**Control measures.** Same as for Rhizoctonia.

### • *Soybean Cyst Nematode (SCN)*

**Symptoms.** Severely infected plants are stunted and yellow. The yellowing often resembles potash or nitrogen deficiency. Damage first appears in oval spots in the field. The roots of infected plants are smaller than normal, have few Rhizobium nodules,

and usually show signs of root decay. If you dig up plants and carefully wash the soil from the roots, you will see pinhead-sized, pear-shaped, white to brown cysts on the roots.

**Conditions.** The soybean cyst nematode survives as eggs in the protective cyst. Most eggs hatch within one or two years, although some may remain unhatched for up to 15 years. Anything that moves infested soil will move the nematode. Equipment and soil peds in uncleaned seed lots are the most common means by which the nematode is spread, although wind, run-off water, birds, or other animals may carry soil containing cysts. Development of the disease is favored by low potash fertility and dry soil. The disease is usually most severe in sandy soils and less severe in heavy silt loam soils. Continuous soybean production favors buildup of nematode populations in the soil.

**Control measures.** Effective, long-term control requires the use of crop rotation and resistant varieties. Be sure to choose varieties that are resistant to the race or races of SCN in your fields. You should rotate soybeans with a nonhost crop because continuous cropping to a resistant variety will lead to buildup of a race that can attack the variety. Before planting a susceptible variety, rotate with a nonhost crop for two to three years. Then have a soil analysis made for SCN to be sure that nematode populations are below the economic threshold.

High potash fertility and early planting have been shown to reduce damage from SCN. Nematicides are also effective. Thoroughly wash soil from equipment that has been used in infested fields before using it in noninfested fields. Weed control may also help since many weeds are hosts of SCN.

### • *Other Nematodes*

**Symptoms.** The symptoms of other nematodes, such as root-knot, dagger, root-lesion, sting, and lance, are similar to those of SCN, but these nematodes produce no cysts on the roots. You may, however, observe root galls caused by the root-knot nematode.

**Conditions.** Same as for SCN, except that problems with these nematodes may develop where corn or other nonlegumes are grown in the rotation.

**Control measures.** Varieties that are resistant to the root-knot nematode are available. Crop rotation or nematicides can be used for control of all nematodes. Before applying nematicides, have a soil analysis made to determine whether nematode populations are high enough to warrant application.

### • *Septoria Brown Spot*

**Symptoms.** Small, angular, chocolate to reddish brown spots appear on the lower, older leaves and then progress upward. These spots are usually most evident as the soybean canopy begins to close. They are accompanied by yellowing of the leaves and premature defoliation. With a hand lens, you can observe small black specks within the spots. These specks are the fruiting structures (pycnidia) of the Septoria fungus.

**Conditions.** The spores of the fungal pathogen are spread to susceptible leaves by wind and rain during prolonged warm, wet weather. The fungus survives the winter in infected crop debris and may be seedborne. The disease is most serious as the canopy closes the rows and pod fill begins. The disease occurs earlier in narrower row spacings.

**Control measures.** Aerial application of fungicides during pod fill reduces the incidence of this disease and is recommended for seed production fields or grain fields where yield is expected to be high. Crop rotation and deep plowdown of crop debris will also aid in reducing this disease.

### • *Powdery Mildew*

**Symptoms.** The fungus causing the disease produces a thin, superficial, white to pale gray, powdery growth (mycelium) over the surface of the leaf. The underside of the leaf may be reddened, or if the disease is severe, leaves turn brown and drop prematurely. Late in the season you may be able to observe with a hand lens small black specks (cleistothecia) in the white powdery mycelium. The cleistothecia are the overwintering stage of the fungus.

**Conditions.** Warm, dry days and cool nights favor development of the disease. Spores produced on infected leaves are spread by wind.

**Control measures.** When possible, plant resistant varieties. Crop rotation and clean plowdown of soybean debris are not effective because the fungus can spread through the air over long distances.

### • *Downy Mildew*

**Symptoms.** Yellowish green spots (lesions) with undefined margins appear on the upper leaf surface. The lower surfaces have grayish tufts of fungal growth. As the disease progresses, the lesions may enlarge and turn yellow to dark brown. Seed infection is indicated by a dense white crust on the surface.

**Conditions.** The downy mildew fungus survives between crops in infected crop residues or on seed. Development of the disease is favored by cool, moist weather, narrow row spacing, or by other conditions that slow the drying of leaves after rainfall or dew.

**Control measures.** You can keep downy mildew in check by planting disease-free seed of resistant varieties, by rotating crops, and by practicing clean tillage. The effectiveness of resistant varieties may

be limited because many new races have developed. At present, over 20 are known. Economic losses rarely occur where soybeans are planted in conventionally spaced rows.

## *Phyllosticta Leaf Spot*

**Symptoms.** Pale green to tannish gray, V-shaped spots (lesions) appear mostly at the edges of the unifoliate or first trifoliate leaves of young plants.
**Conditions.** The fungus survives between crops on crop residue and is spread by splashing water. Development of the disease is favored by extended periods of cool, moist weather.
**Control measures.** Because this disease is relatively unimportant, no direct control measures are necessary. Crop rotation and clean tillage will reduce incidence of the disease.

## *Bacterial Blight*

**Symptoms.** The early symptoms are small, angular, yellow to dark reddish brown or black leaf spots that have water-soaked margins and are bordered by a yellow green halo. The spots may merge to produce large dead areas. These dead areas tear and later drop out, giving the leaf a ragged appearance. Pod infections appear as brown to black blotches, but this symptom alone is not definite proof that the pods are infected.
**Conditions.** The organism that causes bacterial blight survives between crops on crop debris or in infected seeds. The bacterium is spread by wind and rain or in infected seed and is favored by cool, wet, windy weather from early June to mid-July.
**Control measures.** You can control this disease by avoiding highly susceptible cultivars, rotating crops, practicing clean tillage, and planting disease-free seed. Avoiding cultivation when plants are wet will help limit spread of the disease. Do not keep seed from heavily infected fields because infected seed is usually of poor quality.

## *Bacterial Pustule*

**Symptoms.** The first symptom of bacterial pustule is the appearance of small, angular, yellowish green leaf spots with dark reddish brown centers. The spots do not have watersoaked margins. The center of the spot is raised to form a whitish pustule, which is especially noticeable on the lower leaf surface. Dead tissues may tear away, giving the leaf a ragged appearance like that caused by bacterial blight.
**Conditions.** The bacterium survives between crops in the same way as the bacterial blight organism. Development of the disease is favored by warm, wet, windy weather from late June to mid-August.
**Control measures.** Many highly resistant cultivars are available. The cultural practices used for bacterial blight are also effective in controlling this disease.

## *Wildfire*

**Symptoms.** This bacterial disease produces light brown to black leaf spots up to ½ inch in diameter. The lesions are bordered by a broad yellow halo. This disease is usually found with bacterial pustule.
**Conditions.** The causal bacterium survives between crops on crop debris and is favored by the same conditions as bacterial pustule.
**Control measures.** Same as for bacterial pustule.

## *Soybean Viruses*

**Symptoms.** The most common soybean viruses are soybean mosaic, bean yellow mosaic, bean pod mottle, and bud blight (tobacco ringspot). The symptoms of virus infection vary according to the strain of the virus, the age of the plant at the time of infection, and the weather. The leaves may be dwarfed, crinkled, puckered, ruffled, or mottled with light green or yellow (mosaics or bean pod mottle). Plants may be stunted, and the growing point may die on young plants (bud blight or severe strains of soybean mosaic virus). The pods may be stunted, flattened, or curved and have few or no seeds.

Bud blight infections on the pods often appear as rusty brown to purple blotches; the plants commonly have no pods at maturity. Bud blight is most evident late in the season; infected plants stay green until frost. These plants are generally stunted and have little if any seed set. Bud blight is usually most severe at the edges of the field.

Seed produced on plants infected with the soybean mosaic virus may have a brown to black mottling or discoloration of the seed coat. But this symptom alone does not prove that the seed is infected with the virus.
**Conditions.** Soybean viruses survive between crops in seed or, more commonly, in infected perennial weeds or legumes such as clovers or alfalfa. The soybean mosaic virus is spread by infected seed and many species of aphids. The bean yellow mosaic virus is spread by several types of aphids. The bean pod mottle virus is spread most commonly by the bean leaf beetle, although other beetles feeding on soybeans may transmit it. Bud blight is spread primarily by the nymphs of thrips, although grasshoppers and other insects as well as dagger nematodes may also transmit it. Bud blight is also commonly spread by seed. This is the most important means by which long-distance spread occurs.

Disease is much more likely to develop if conditions favor the insects transmitting the virus and

allow perennial weeds or legume crops to grow near soybeans. Dry conditions may increase damage from the bean pod mottle virus.
**Control measures.** Plant disease-free seed, and control perennial broadleaf weeds in ditches, fencerows, and pastures. Planting borders of four to eight rows of corn between soybeans and adjoining clover or alfalfa fields may reduce damage. It is also a good idea to remove infected plants from seed production fields.

## Bloom to Harvest

### • *Charcoal Rot*

**Symptoms.** Plants lack vigor and exhibit poor growth and pod set. The leaves turn yellow, wilt, and die prematurely, often remaining attached to the plant. You can see numerous black specks (sclerotia) if you scrape the bark away from the taproot or stem base. These small sclerotia, which resemble a sprinkling of finely ground charcoal, may give the internal tissues a grayish black appearance. If you cut open the taproot or stem base, you will observe that the sclerotia appear as black streaks.
**Conditions.** The charcoal rot fungus is present in most agricultural soils in the southern two-thirds of Illinois and may be spread by movement of infested soil or by infected seeds. It survives as sclerotia in the soil or infested crop residues for long periods. Besides soybeans, the fungus attacks corn, sorghums, alfalfa, clovers, and many other plants. The fungus survives better in dry soils than in wet soils and is most damaging when the soil temperature is high. Low potash and phosphorus fertility, crowding, and continuous cropping to host plants also increase the severity of the disease.
**Control measures.** Avoid seeding at high rates. Clean plowdown of crop residues may decrease sclerotia survival if the soil is wet between crops. Maintain high potash and phosphorus fertility. It may also be helpful to plant full-season varieties early and avoid moisture stress.

### • *Sclerotinia Stem Rot or White Mold*

**Symptoms.** Plants die soon after bloom with the leaves remaining attached. A white, cottony mold forms on the foliage and lower stems. At first, this mold growth or light tan cankers can usually be seen in the center of infected plants. Large (up to ½ inch), black sclerotia form in the cottony mold growth, inside stems, and occasionally in pods.
**Conditions.** The white mold fungus survives between crops as sclerotia. The sclerotia may develop within previous host crops, such as garden beans, sunflowers, alfalfa, and clovers, or from weeds in noncrop areas. Sclerotia are often a contaminant in seed. Under high moisture conditions, microscopic spores are produced on the soil surface from small, trumpet-shaped fungus structures (apothecia) that originate from sclerotia. These spores infect blossoms that are covered with moisture. Extended wet periods just prior to and through bloom are necessary for infection. Dense foliage and rotation with other host plants favor development of the disease.
**Control measures.** Plant resistant varieties, and avoid rotations with garden beans, sunflowers, or other host crops. Do not irrigate during bloom. Certain fungicides applied during bloom may also control the disease. Seed lots should be thoroughly cleaned to remove sclerotia.

### • *Stem Canker*

**Symptoms.** Scattered plants or groups of plants wilt and die with the dried leaves remaining attached. Dark reddish brown, later tan, girdling cankers form at the base of the branches on the stem, usually at the fourth or fifth nodes, from mid-July to harvest.
**Conditions.** The stem canker fungus survives between crops in infected crop residues or infected seed. The fungus is spread by waterborne spores or by infected seed. Development of the disease is favored by extended periods of warm, wet weather from June until near harvest.
**Control measures.** Crop rotation, clean plowdown of infected crop residues, planting of disease-free seed, and application of certain foliar fungicides will provide acceptable control.

### • *Pod and Stem Blight*

**Symptoms.** Near-mature or mature plants have numerous black specks (pycnidia) scattered over the stems. These are often concentrated in patches near nodes or on the lower stem. Some strains of the fungus form pycnidia in straight rows. The pycnidia are usually scattered on the pods. Heavily infected seeds are dull, discolored, cracked, and shriveled and frequently are partially or completely covered with white mold growth. Seedlings from infected seed may develop reddish brown streaks on the hypocotyl and brown to reddish lesions on the cotyledons. The growing point may decay. Seedling blight may make plants weak and spindly or kill them.
**Conditions.** The pod and stem blight fungus survives between crops in infected soybean residues or infected seed. The pathogen is spread by airborne and waterborne spores or infected seed. Warm, wet conditions from bloom until harvest favor infection.
**Control measures.** Crop rotation, clean plowdown of crop residues, planting of disease-free seed, and application of certain foliar fungicides will give good control. Fungicide seed treatments may be helpful

if you have to plant infected seed. This seed should be thoroughly cleaned to remove lightweight, severely infected seeds.

### *Anthracnose*

**Symptoms.** Infected pods or stems at first show irregularly shaped, reddish brown or dark brown areas that are later covered with tiny black spines (setae) arising from cushion-shaped fungal fruiting bodies (acervuli). The setae appear as tiny black spines under magnification. Severely infected seed may be moldy, dark brown, and shriveled.
**Conditions.** Same as for pod and stem blight.
**Control measures.** Same as for pod and stem blight.

### *Brown Stem Rot*

**Symptoms.** Plants wilt and die prematurely. The leaves on infected plants may first turn brown between the veins. Severely infected groups of plants have a brownish cast that resembles frost damage rather than the yellow green of normally maturing soybeans. If you split an infected stem, you will notice a reddish brown discoloration of the pith and vascular tissue. This browning is at first most prominent in the lower stem.
**Conditions.** The fungus survives between crops in infected crop residues or in soil. It usually survives for only two to three years in the absence of soybean or clover hosts. The fungus is spread by movement of infested soil or diseased crop residue. Development of the disease is favored by cool weather from June to mid-August.
**Control measures.** Plant resistant or early maturing varieties. Rotation with corn or other nonhost plants for two or three years provides good to excellent control.

### *Frogeye Leaf Spot*

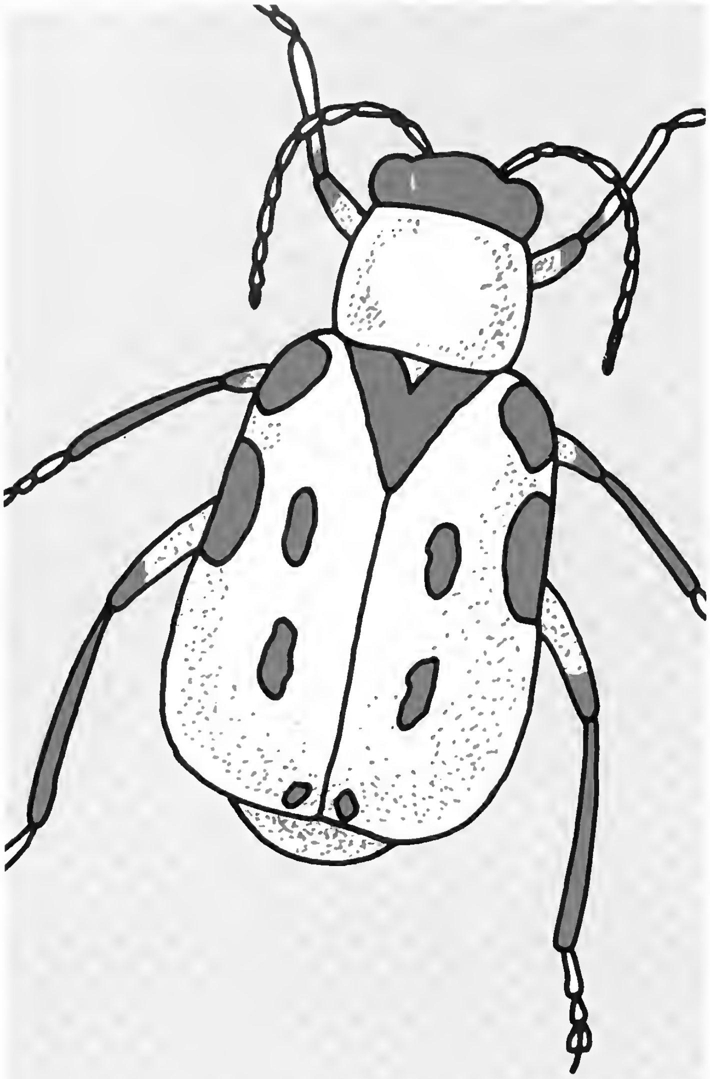
**Symptoms.** Infections first appear as minute, reddish brown, circular to angular leaf spots. The lesions enlarge with age, the center becomes olive gray or ash gray, and the border becomes a dark reddish brown. Similar spots may also develop on the stems and pods. Infected seeds develop conspicuous light to dark gray or brown areas, which vary from minute specks to large blotches that cover the entire seed coat.
**Conditions.** The fungus survives between crops in infected plant debris or in infected seed and is spread by airborne spores or infected seed. Development of the disease is favored by warm, wet weather, and possibly by narrow row spacing.
**Control measures.** Resistant varieties are available for both races 1 and 2. Crop rotation, clean tillage, and planting of disease-free seed will minimize development of the disease.

### *Cercospora Purple Seed Stain and Leaf Blight*

**Symptoms.** Soybean seed, pods, leaves, and stems are all affected by the disease. The most conspicuous and easily distinguished symptom is the characteristic pink to purple discoloration of the seed coat. Cotyledons on plants developing from infected seed are often shriveled and purple. After bloom, the upper leaves are often infected, causing premature bronzing or yellowing. If you examine early infected plants, you will notice angular reddish brown spots on both leaf surfaces. These spots coalesce to form larger spots that have a crusted appearance. Defoliation typically occurs from the top down. Stem, petiole, and pod infections are characterized by slightly sunken, irregular reddish purple spots.
**Conditions.** Same as for frogeye leafspot.
**Control measures.** Planting of disease-free seed, crop rotation, and clean plowdown of infected crop residue will help retard development of the disease. Application of certain foliar fungicides will help control the leaf blight and seed stain phases of the disease.

### *Storage Molds*

**Symptoms.** Grain becomes discolored or moldy in storage.
**Conditions.** Storage mold fungi can grow when the moisture content of the soybeans is 11 percent or greater and the relative humidity is 60 percent or greater. High temperatures also favor development of storage molds. Broken, cracked, or diseased seed is especially susceptible to infection.
**Control measures.** Store soybeans at a moisture level of 10 to 13 percent under cool conditions and at a relative humidity under 40 percent.



# Insect Pests

More than 20 insect species and related pests, such as mites, attack the soybean plant during the various stages of its growth. In addition, many beneficial species prey on or parasitize the plant-damaging species.

Beneficial insects, weather, and other conditions often keep the populations of soybean insect pests below economically damaging levels. Occasionally, however, severe outbreaks of certain soybean pests occur, making control measures necessary. In 1973, for example, more than 700,000 acres of soybeans in Illinois were sprayed for green cloverworm control.

Several of the soybean pests are capable of causing drastic reductions in yield. Many reduce yield indirectly through defoliation or leaf feeding, and others feed directly on the soybean flowers and pods. Fortunately, when moisture and temperature are favorable for plant growth, soybeans can tolerate a considerable amount of damage from leaf feeding without suffering significant yield loss. Direct damage to the pods or heavy defoliation during the bloom and pod-fill stages, however, will usually cause significant yield loss.

Soybean insect pests can be divided into four groups according to the part or stage of the plant they attack: some attack the soybean seed or plant belowground; some attack only the soybean seedling; others are foliage feeders; and a few are pod feeders.

The pests that attack belowground and those that attack the seedlings occur early in the season. Seedcorn maggots, white grubs, wireworms, and grape colaspis feed on the seed, roots, or underground portion of the stem soon after the soybeans are planted. Bean leaf beetles or black cutworms may attack young plants emerging from the soil.

Insects that feed on the foliage of soybeans include bean leaf beetles, southern corn rootworm beetles, Japanese beetles, grasshoppers, blister beetles, woollybears, and green cloverworms. Mexican bean beetles and velvetbean caterpillars also feed on soybean leaves, but they are seldom found in Illinois soybean fields.

Pests that suck plant juices from the foliage include spider mites, thrips, and plant bugs. Direct damage to the soybean pods is caused by stink bugs, grasshoppers, corn earworms, and bean leaf beetles.

Outbreaks of soybean pests are sporadic and cannot be predicted from one year to the next. Over the past several years, green cloverworms, bean leaf beetles, grasshoppers, and spider mites have caused the most damage to Illinois soybeans. These and other pests are discussed in the following section.

# Identification

Various insects feed on and damage soybean plants from the time the soybeans are planted until harvest. Although most of the pests are present every year, they cause economic damage only occasionally. You should become familiar with the more common insect pests and learn when and how they cause damage. This section briefly identifies each insect pest, describes the damage it causes, and tells approximately when the damage is most likely to occur. Occasionally, you may confuse some type of insect damage with the symptoms of disease, nutrient deficiency, herbicide injury, or with some other problem. But if you know the symptoms well, you should have little difficulty identifying insect damage, especially if you can also identify the insect itself (for color illustrations of common insect pests and symptoms of other problems, see pages 45 to 52).

## Early Season

Several insects feed on the belowground portions of the soybean plant early in the season. The aboveground symptoms of this feeding range from noticeable gaps in soybean rows and a reduced stand to stunted, yellow, or dead plants. The damage usually occurs in scattered areas of the field.

Planted seeds are attacked by **seedcorn maggots.** These white, legless larvae are tapered toward the head end. Because the maggots eat out the germ of the seed, plants may fail to germinate. Plants that do germinate will be weak and often die. Seedcorn maggots usually cause damage where the soil is high in organic matter content and when cool, wet weather delays soybean germination.

Two types of grubs feed on soybean roots: grape colaspis and white grubs. Like all other grubs, the **grape colaspis** is white and has the characteristic C-shape, but it is smaller (about ⅛ inch) and has much shorter legs than the other types. It causes damage primarily to soybeans planted after clover, alfalfa, or previously infested soybeans. Several species of **white grubs** also attack soybean roots. They range in size from ½ inch to 1¼ inches, depending on the species and the larval stage. All of them are white and have a brown head and the characteristic C-shape. The true white grub has a three-year life cycle. Root feeding and pruning by all grubs reduce water and nutrient uptake by soybean plants. The leaves turn yellow and brown and may die. The plants may be stunted or wilted. You can find grubs easily by digging in the rows in infested areas.

**Wireworms** attack the planted seed and the underground parts of the seedling. Wireworms range in size from ½ inch to 1½ inches long and resemble short pieces of rusty wire. They have hard shells and very short legs. They drill into the seed and lower portions of the stem. Damaged plants appear yellow, and many seeds may fail to germinate.

As soon as the soybean seedling emerges from the soil, it becomes subject to damage from another group of insects. **Black cutworm** larvae occasionally occur in soybean fields and cut plants off at the soil level. These large, greasy appearing, gray to black worms may drastically reduce the stand in a soybean field.

**Bean leaf beetles** feed on several plant parts of newly emerged soybeans. The small, reddish to yellow, usually spotted beetles chew on the hypocotyl and cotyledons of newly emerged seedlings. Extensive feeding by this pest will destroy many plants. The beetles also feed on the foliage of young soybean plants. Damaged leaves look as if they have been shot full of holes.

Damage caused by **thrips** is easily recognized in soybeans during the early part of the growing season. These tiny, yellow to brown insects rasp the leaf surface and suck the sap from soybean plants. Small, white, speckled streaks appear on the leaves, and the field soon takes on a silvery cast. Thrips migrate to soybean fields from other crops and certain wild grasses. If the soybeans are under moisture stress, thrips damage will be more severe.

Other early season pests include **seedcorn beetles,** which feed on the seeds, and **southern corn rootworm larvae** and **bean leaf beetle larvae,** both of which feed on the underground portions of the plant. **Southern corn rootworm beetles, clover leaf weevils,** and **clover root curculios** may feed on soybean foliage, but these insect pests rarely cause serious problems.

## Midseason

Most of the midseason soybean insect pests are defoliators, or foliage-feeding insects. The **Japanese beetle** is a strikingly colored insect that occasionally feeds on soybean leaves in eastern Illinois. It has a metallic-green body, copper-colored wing covers, and distinctive white tufts along the sides of its abdomen. There are two prominent white tufts at the tip of the abdomen. The beetle usually feeds between the leaf veins and on soybean blossoms during mid-to-late July.

**Grasshoppers** begin migrating into soybean fields from nearby fencerows, grass waterways, roadsides, ditch banks, and hay fields during early-to-mid-July. Since by that time of the season they have usually depleted their food supply in the noncrop areas, they move into soybeans and other crops in

search of food. Although they feed primarily on the leaves, they will also feed on stems and pods. The grasshoppers usually cause damage first at the edges of a field. As they continue to move through it, the entire field may take on a ragged appearance as a result of extensive leaf feeding.

**Twospotted spider mites** can be found in soybean fields from July through August. These minute, six- or eight-legged insect relatives rasp the leaf surface and feed on exuding sap. They feed primarily on the undersides of leaves, giving the damaged leaves a speckled appearance. The leaves may eventually turn yellow and die. The damage is most severe during hot, dry weather. You will usually notice it first at the edges of the field. Another sign of the presence of spider mites is a coating of fine, white webbing on the undersides of the leaves. If you examine these leaves closely, you can see the mites, which appear as tiny, moving specks.

### Late Season

Many insects attack the soybean plant from podding to harvest. One pest that can occasionally cause severe damage is the **green cloverworm.** This light-green worm has two, thin white stripes along each side of its body. It moves by arching its body, and it flips violently from side to side when disturbed. Cloverworms eat holes in the leaves of the upper portion of the plant. Severely damaged fields appear ragged. The worms may also feed on the blossoms.

Several other worms defoliate soybean plants, but they usually cause only minor damage or seldom occur in Illinois. The **cabbage looper, garden** and **alfalfa webworms,** and **fall armyworms** all feed on soybean leaves late in the season. The **woollybear** occasionally reaches economically damaging levels during the year following a mild winter. The **velvetbean caterpillar** and the **corn earworm** pose severe problems in the southern United States but rarely cause damage in Illinois soybeans.

The second generation of **bean leaf beetles** causes damage to soybeans late in the season. They feed on the leaves, giving them a shot-hole appearance, and they may also damage the pods. Damaged pods may become moldy.

Several species of **blister beetles** may feed on soybean foliage. These elongate, soft-bodied beetles resemble large lightning bugs and have a prominent "neck." The species most commonly found on soybeans is the striped blister beetle, a brown to gray beetle that has yellow stripes running the length of its wing covers. Blister beetles occur in clusters. Their feeding is rarely a problem. In fact, they can be beneficial since the immature stages of blister beetles feed on grasshopper eggs and sometimes reduce grasshopper populations.

The **Mexican bean beetle** is primarily a pest of garden beans. Although it has not yet caused damage to Illinois soybeans, it has become a serious problem in some neighboring states. The beetles are yellow to copper colored and have 16 black spots on their wing covers. The larvae are yellow and have six rows of long, branching, black-tipped spines on the back. Both stages feed on the leaves, and the beetle also damages pods. The larvae feed only on the undersides of leaves, exposing the lacelike structure of the leaf veins.

**Green** or **brown stink bugs** can be found in soybean fields by late July. They are more of a problem in southern Illinois than in other parts of the state. These shield-shaped bugs suck the sap from the plant or pods with their long beaks. Their feeding may reduce the yield and quality of soybeans and cause them to become discolored and shrunken. Damaged pods often drop to the ground. Badly damaged beans may be downgraded at the grain elevator.

## Control

The key to controlling soybean insect pests in Illinois is to adopt sound pest management principles and practices. You should scout your fields and collect samples regularly, be certain that you understand the current economic thresholds and apply pesticides only when insect populations have reached those levels, and use control measures efficiently. Although efficient management of insect pests takes extra time and effort, the results make it worthwhile.

Begin sampling early in the growing season, and continue at intervals throughout it. As a rule of thumb, you should scout your soybean fields at least six times each season. Sampling is especially critical during the bloom, pod-set, and pod-fill stages. Defoliation or damage from leaf-feeding results in much greater yield loss during these stages than during the vegetative stage of growth, especially if the plants are under moisture stress. In fact, it takes as much as 35 percent defoliation during vegetative growth to cause a significant yield loss, but only 15 percent during the pod-set and fill stages. If defoliation by one or several types of insects exceeds 15 percent during those critical stages, an insecticide treatment is justified.

Once you have identified the pest or pests in your fields, you need to determine whether an insecticide application is necessary. You should apply pesticides only when the insect population has reached the economic threshold. The economic threshold is the population level at which controls should be applied to prevent economic crop injury.

This threshold depends upon the number of insects, the amount of damage they cause, the cost of control measures, the cash value of the crop, and several other factors.

Scouting procedures and economic thresholds for the four primary soybean pests in Illinois are described in the table below. Although the thresholds may vary as soybean cropping practices change, they provide a sound basis for making decisions about insecticide application. The table on page 44, top, gives the specific combinations of green cloverworm population and percentage defoliation that will significantly reduce yield. The tables following it give the combinations of bean leaf beetle population and degree of injury that will result in a significant yield reduction. Use the specific criteria in the tables to make decisions about control of these pests. Also consider the insect's life cycle and the effect of natural enemies and weather on the pest population.

In some years, populations of insect pests are kept below damaging levels by parasites, predators, and diseases. Cultural practices, such as crop rotation and weed control, will also prevent several insects from becoming major pests. If insects are not kept in check by these means, then it may be time to control them by insecticide application. A good pest management strategy is to treat only when it is absolutely necessary.

Because recommedations for insect control change often, specific insecticides are not listed in this publication. To obtain up-to-date recommendations for control of soybean insects in Illinois, consult the current issue of *Insect Pest Management Guide: Field and Forage Crops*, Circular 899, which you can obtain from your county Extension adviser. Your Extension adviser or a University of Illinois specialist can also give you further information about soybean insect scouting, thresholds, and control.

**Scouting Procedures and Economic Thresholds**

| | Time of attack | Scouting procedure | Economic threshold |
|---|---|---|---|
| Bean leaf beetle | May to June and August | Estimate the percentage defoliation and percentage pod feeding. Estimate the number of beetles per foot of row. | *Prebloom.* 30 percent defoliation. *Bloom to pod fill.* 15 percent defoliation or 10 percent pod feeding. |
| Grasshopper | August | During June, check field borders that you suspect are infested. Estimate the number of grasshoppers per square yard. If they have already migrated into soybeans, pinpoint the infested areas. | 20 or more grasshoppers per square yard in noncrop areas before grasshoppers migrate into soybeans. Base your decision whether to spray soybeans on percentage defoliation and pod feeding. |
| Green cloverworm | July to August | Using a drop cloth, examine 3 linear feet of row in five locations. Shake the plants vigorously on either side of the drop cloth to dislodge the worms, and determine the number per linear foot of row. Estimate the percentage defoliation. | *Bloom to pod fill.* 12 or more half-grown worms per foot of row and 15 percent defoliation. |
| Spider mite | July to August | Sample border rows of soybeans, particularly where plants are taking on a yellowish cast. To determine the presence of mites, shake leaves over a sheet of white paper. Dislodged mites may be observed crawling on paper. A 10X hand lens is helpful in detecting mites. | None established. Treatment is usually justified when plants along field margins are showing leaf discoloration caused by spider mite feeding. |

### Green Cloverworm

| Percentage defoliation | Number of green cloverworms (longer than ½ inch) per foot of row | | |
|---|---|---|---|
| | Fewer than 8 | 8 to 12 | More than 12 |
| 0 to 20 | Continue sampling at regular intervals. | Continue sampling at closer intervals. | Apply a preventive treatment. Probability of yield loss is low. |
| 20 to 30 | Continue sampling at closer intervals. | This is the correct time to spray. There should be no yield loss. | Spraying is overdue. Minor yield loss is probable. |
| More than 30 | Continue sampling at closer intervals. Yield loss is probable. The insect population is on the decline. | Spraying is overdue. Yield loss is probable. | Spraying is much overdue. Major yield loss is probable. |

### Bean Leaf Beetle (Early Season)

| | Number of beetles per foot of row | | |
|---|---|---|---|
| Amount of injury | Fewer than 4 | 4 to 6 | More than 6 |
| Cotyledons slightly injured; less than 30 percent injury to unifoliolate and open trifoliolate leaves | Sample again by late July. | Sample again within 1 week. | Sample again in 3 days. |
| At least one cotyledon completely destroyed; 30 to 40 percent injury to unifoliolate and open trifoliolate leaves | Sample again in 3 days. | This is the correct time to spray. There should be no yield loss. | Spraying is overdue. |
| Two cotyledons destroyed; more than 40 percent defoliation | Sample in 3 days; if plants are dying, some replanting may be needed. | Spray; if plants are dying some replanting may be needed. | Spray; if plants are dying, some replanting may be needed. |

### Bean Leaf Beetle (Late Season)

| Percentage of pod injury | Number of bean leaf beetles per foot of row | | |
|---|---|---|---|
| | Fewer than 8 | 8 to 10 | More than 10 |
| Less than 8 | Discontinue sampling. | Sample again in 5 days. | Spray if pods are still green. |
| 8 to 12 | Sample again in 5 days. | Spray if pods are still green or beginning to yellow. | Spray if pods are green or beginning to yellow. |
| More than 12 | Spray if pods are still yellow and beetles are present. | Spray unless pods are completely dry. | Spray unless pods are completely dry. |

## Nutrient Deficiency

(See the discussion on pages 10 to 12.)

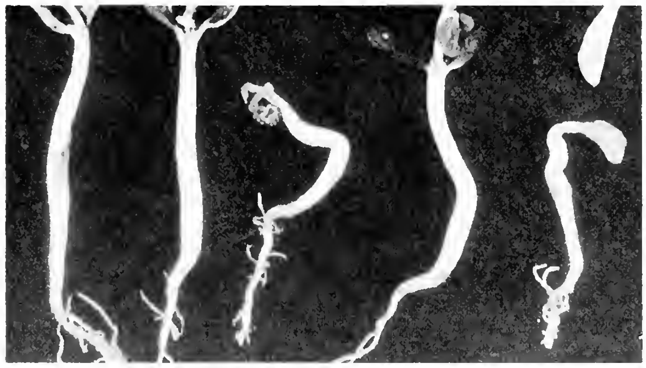
**Potassium** (page 10)

**Iron** (page 12)

**Manganese** (page 12)

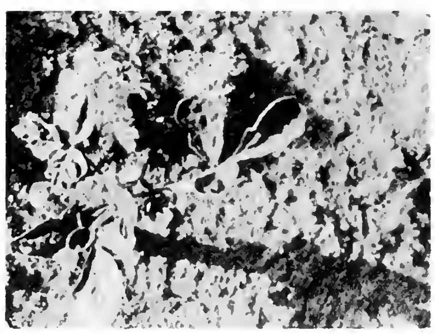
## Herbicide Injury

(See the discussion on pages 29 to 30.)



**Dinitroaniline herbicide.** Injury to germinating plant from excessive rate.

**Acetanilide herbicide.** Crinkled leaves, top left; "drawstring" effect, right.



**Vernam.** Crinkled leaves, left; leaflets sealed together, right.


Triazine herbicide


Lorox


Modown and Goal


Basagran


Dyanap


Blazer


2,4-DB


2,4-D


Banvel

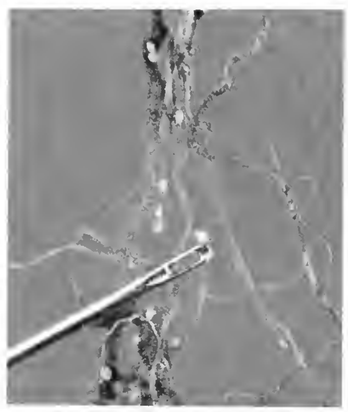
## Plant Diseases

(See the discussion on pages 35 to 39.)

**Pythium or Phytophthora seedling rot** (page 35)

**Phytophthora root and stem rot** (page 35)

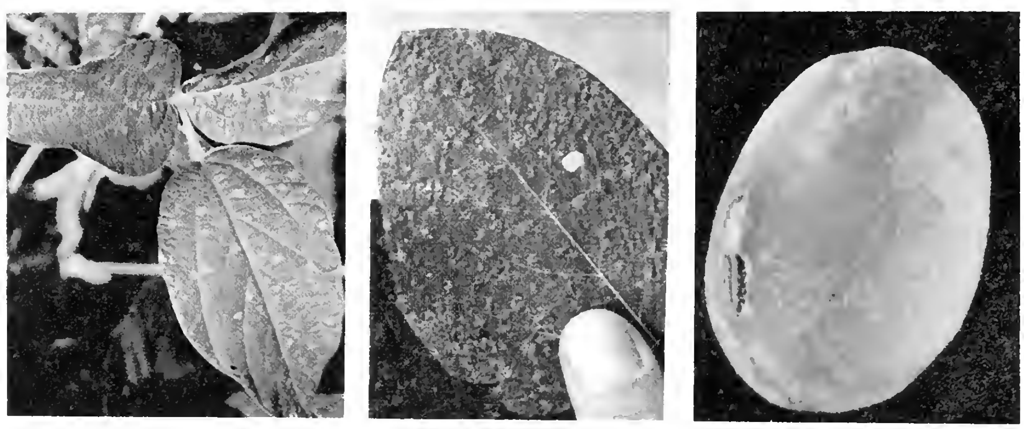
**Rhizoctonia root rot** (page 35)



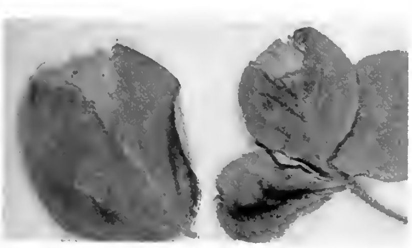
**Soybean cyst nematode** (page 35). Field damage, left; cysts on roots, right.

**Septoria brown spot** (page 36)

**Powdery mildew** (page 36)

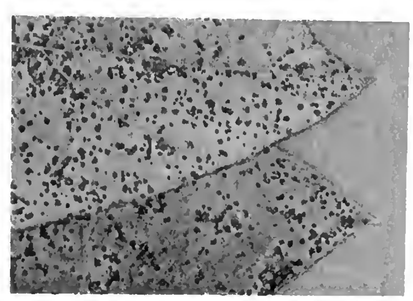


**Downy mildew** (page 36). Upper leaf surface, left; lower leaf surface, center; and infected seed, right.



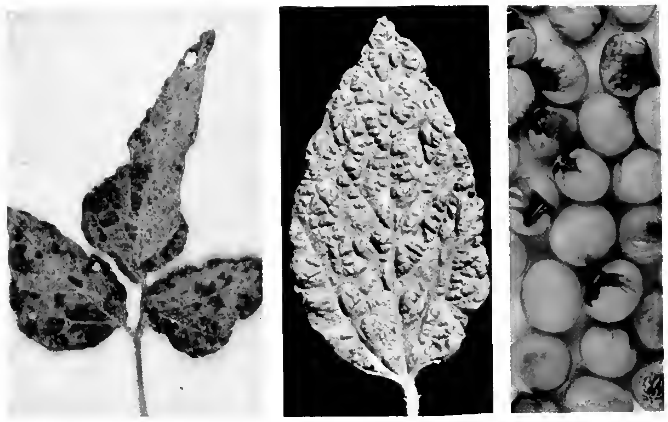
**Phyllosticta leaf spot** (page 37)

**Bacterial blight** (page 37)



**Bacterial pustule** (page 37). Lower leaf surface, top; upper surface, bottom.

**Wildfire** (page 37)



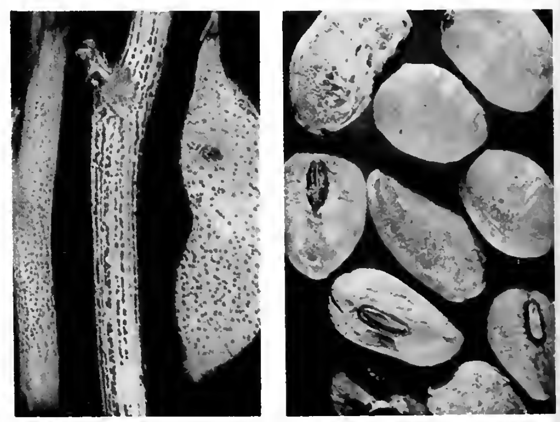
**Soybean mosaic** (page 37). Leaf symptoms, left and center; mottling of seed coat, right.

**Bud blight** (page 37). Blossom malformation and necrosis of terminal buds, left; blotches on pods, right.

**Charcoal rot** (page 38)

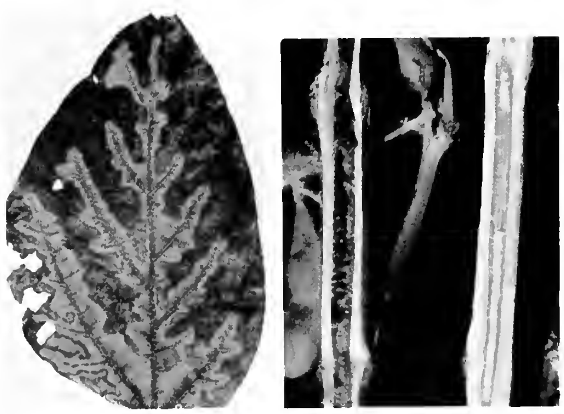
**Sclerotinia stem rot** (page 38). Cottony mycelium, left; sclerotia on stems, right.

**Stem canker** (page 38)



**Pod and stem blight** (page 38). Pycnidia on stems and pod, left; infected seed, right.

**Anthracnose** (page 39)



**Brown stem rot** (page 39)

**Cercospora purple seed stain** (page 39)

# Insect Pests

(See the discussion on pages 41 to 42.)

Seedcorn maggots (5.5X)

**White grub** (2.5X)

**Wireworms** (1.5X)

**Bean leaf beetles.** Common color pattern (3X), left; red form (4.5X), right.

**Black cutworm larva** (1X)

**Early season damage from bean leaf beetle**

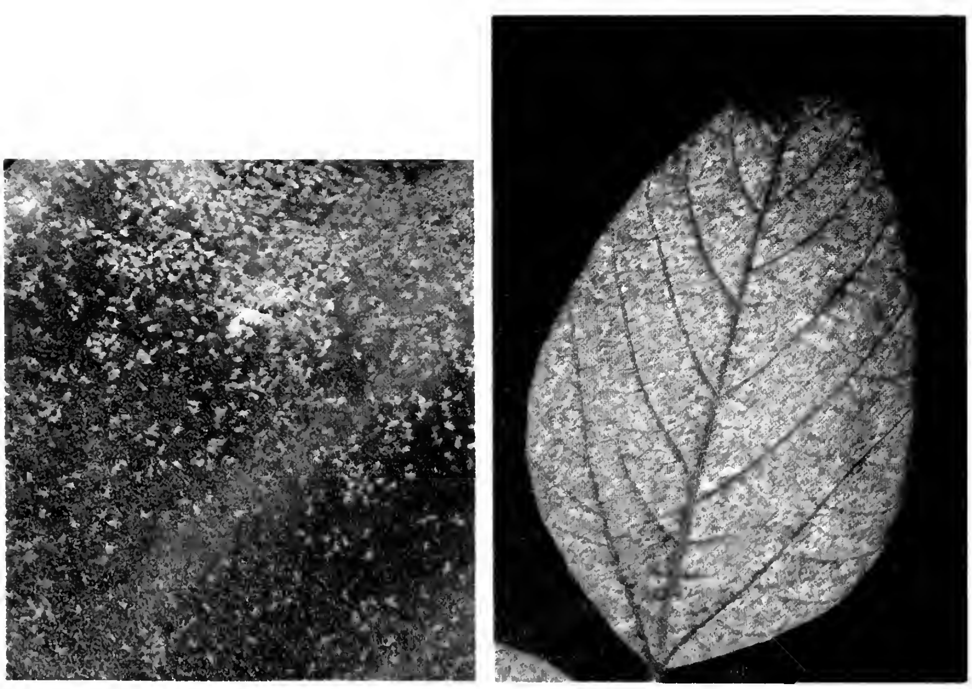
**Thrips** (40X)

Japanese beetles (2X)

Grasshopper (1.3X), left; pod injury, right.

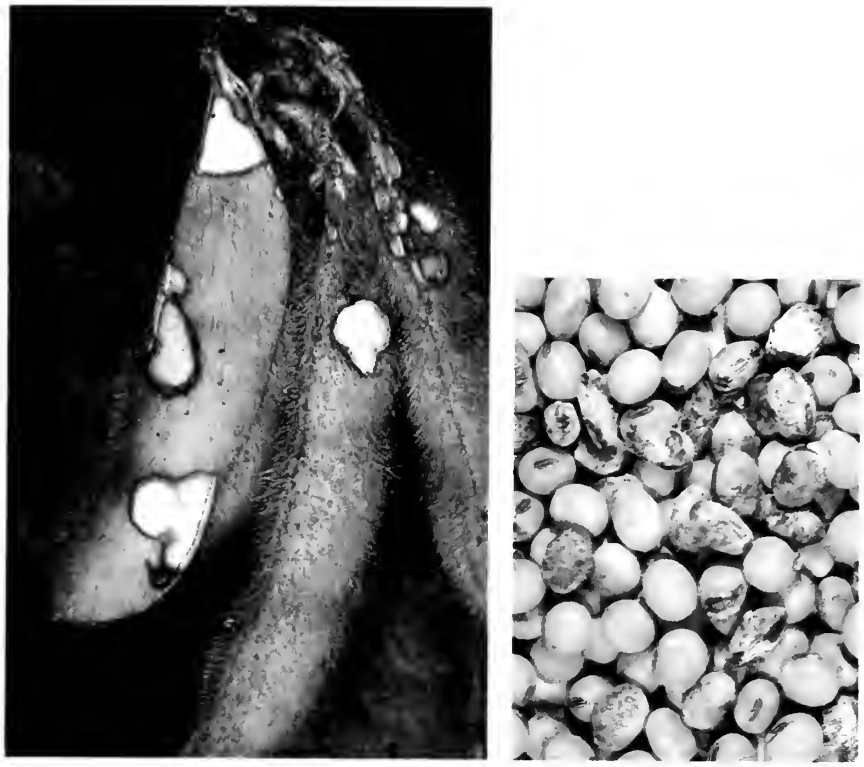
Green cloverworm (2X)

Woollybear (1.2X)



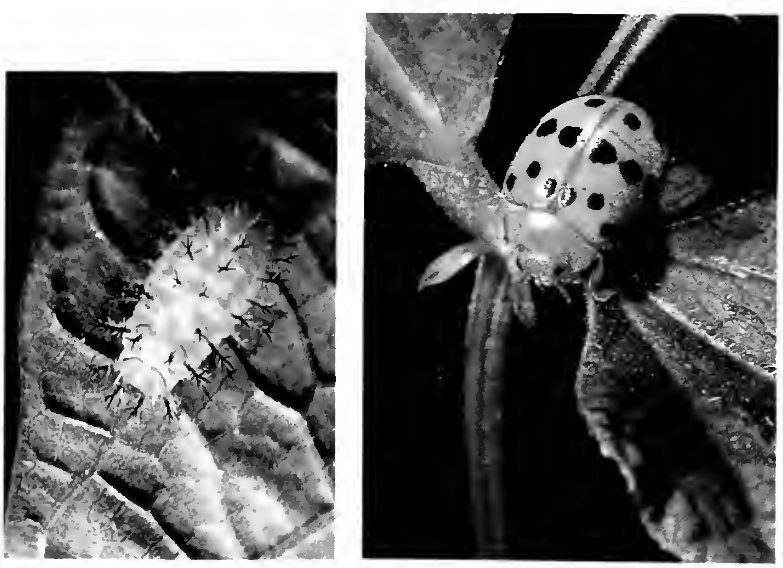
Twospotted spider mites on webbing (6X), left; damage, right.

Corn earworm (1X)

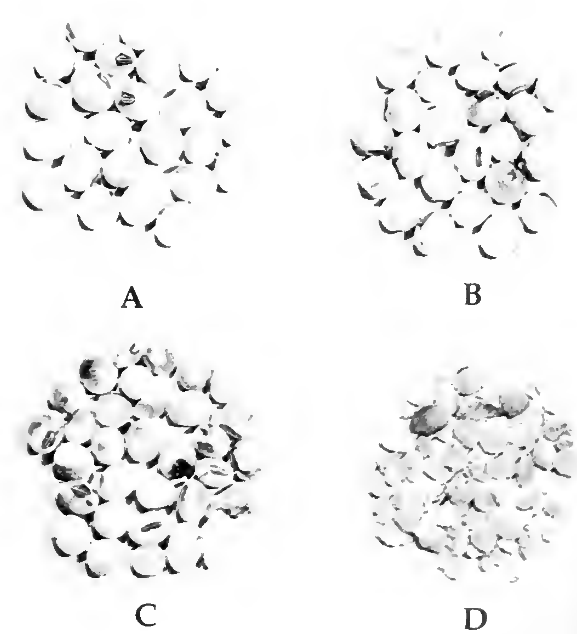


Pod scars caused by bean leaf beetles, left; moldy seed resulting from pod injury, right.

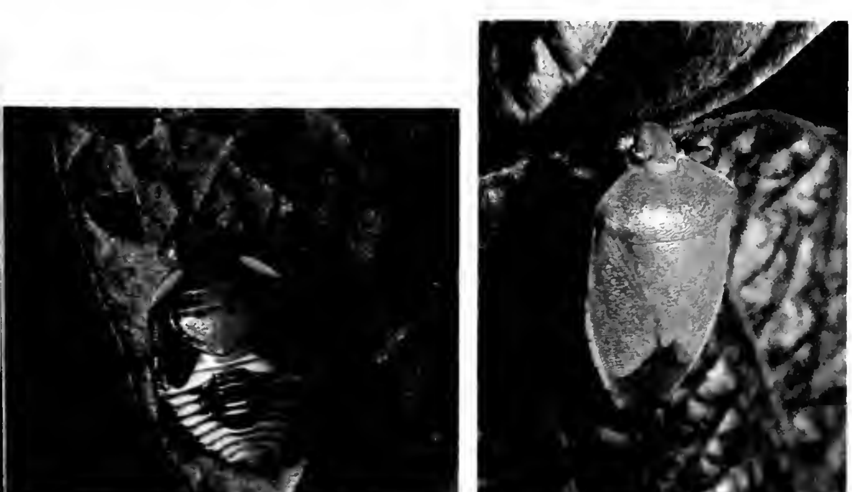
Blister beetles (2X)



**Mexican bean beetle.** Larva (4X), left; adult (4X), right.




**Classes of seed injury by stink bugs:** A, none; B, light; C, medium; and D, heavy.

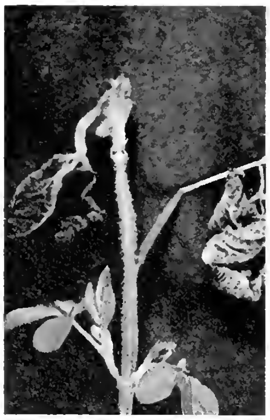


**Green stink bug.** Nymph (2.5X), left; adult (2.5X), right.

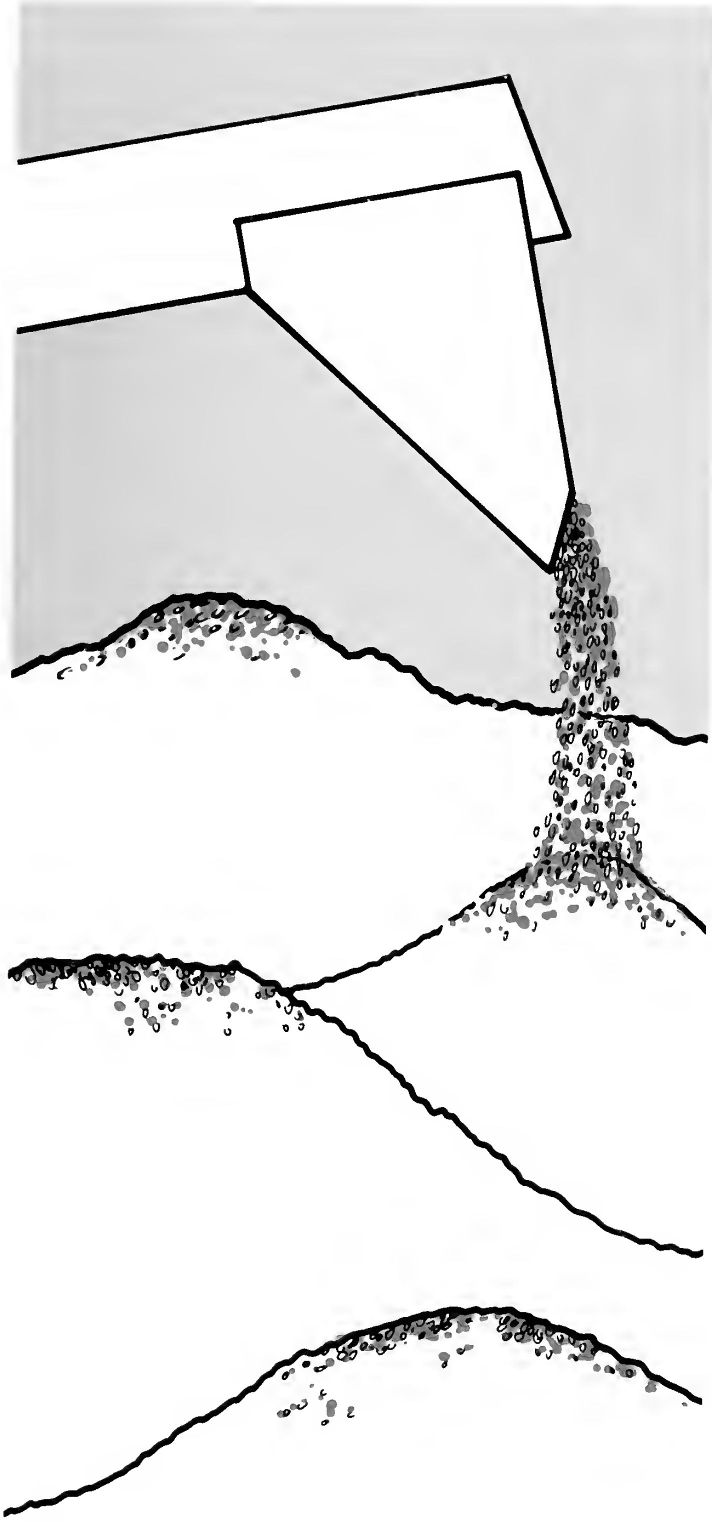
# Other Types of Crop Damage

Lightning damage

Hail damage



Frost damage



# Harvesting, Drying, and Storage

## Soybean Losses During Harvest

Although the grain-combine harvester has been used for soybeans since the midtwenties, little progress was made in reducing soybean harvesting losses until about 1970. At that time the average combine operator, when using a rigid grain platform header, was leaving as much as 10 percent of the crop in the field. The introduction of attachments such as the floating cutterbar and pick-up reel made it possible to reduce harvesting losses to 7 or 8 percent.

More recently, combine headers specifically designed for soybeans have become available. Several combine manufacturing companies have introduced headers that have a built-in flexible cutterbar. A low-profile, row-crop header was introduced by John Deere and Company in 1974.* With these new headers, you can reduce harvesting losses to about 4 percent of yield. An alert combine operator can reduce losses even further under some harvesting conditions.

To keep harvest losses to a minimum, you need to know what types of losses occur, how to measure those losses, and what equipment, adjustments, and practices will enable you to harvest soybeans most efficiently.

### Types of Soybean Losses

Some soybean losses result, not from the operation of the combine, but from natural causes before harvest. These **preharvest losses** are soybeans that have fallen to the ground by the time harvest begins. If soybeans that are ready for harvest are then subjected to several alternating periods of wet and dry weather, your preharvest losses could be as high as 25 percent. To avoid such high losses, you should plant varieties that are resistant to shattering and harvest early. You can usually keep preharvest losses low by harvesting soybeans shortly after their moisture content reaches 13 percent for the first time.

As long as you take these precautions, preharvest losses should account for a relatively small part of your total soybean losses. Your most important con-

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cern will be to reduce losses that occur during the gathering, threshing, separating, and cleaning operations at harvest.

### *Gathering*

**Gathering,** or **header, losses** are soybeans that are not gathered into the combine. These losses are caused by the action of the cutterbar, reel, and auger. They account for more than 85 percent of the total soybean loss at harvest. There are four kinds of gathering losses. **Shatter losses** are shelled beans and detached bean pods that are shattered from stalks by the header and fall to the ground without going into the combine. **Stubble losses** are soybeans in pods remaining on the stubble. **Stalk losses** are soybeans remaining in pods attached to stalks that were cut but not delivered into the combine. **Lodged losses** are beans remaining in pods attached to stalks that were not cut or that were cut at heights greater than that of the stubble.

### *Threshing, Separating, and Cleaning*

Soybeans are easy to thresh, separate, and clean. They can be rubbed out of the pod readily, and their size and shape are ideal for cleaning. Even so, small errors in the adjustment of the combine can result in disastrous losses during the threshing, separating, and cleaning operations. **Threshing,** or **cylinder, losses** occur when unthreshed beans remain in pods that pass through the combine and when beans are cracked by the cylinder. **Separating,** or **straw walker, losses** occur when shelled beans are carried out the back of the machine with the stalks (these losses are usually insignificant unless the combine is overloaded). **Cleaning,** or **shoe, losses** occur when shelled beans are carried over the chaffer, or top, sieve and out the back of the combine.

## Measuring Soybean Losses

The easiest way to measure harvest losses is to enclose an area of approximately 10 square feet within a rectangular frame and count the beans remaining in that area after harvest. If you count 40 beans within the frame, your soybean loss is approximately 1 bushel per acre.

Make the frame from heavy cord or clothesline, so you can coil it and carry it with you on the combine. The length of the frame should be equal to the cutting width of your combine header. Use the list above to determine the width of the frame. Make four pins 3 to 4 inches long from No. 9 wire and tie them to the frame to mark the corners. The pins should be pushed into the ground to hold the frame tight.

| Header width, feet | Frame width, inches |
|---|---|
| 10 | 12 |
| 12 | 10 |
| 13 | 9¼ |
| 14 | 8½ |
| 15 | 8 |
| 16 | 7½ |
| 18 | 6¾ |
| 20 | 6 |
| 22 | 5½ |
| 24 | 5 |

Researchers at The Ohio State University have developed the following procedure for determining field losses (see drawing on page 55). Operating the combine in the normal way, move into the crop until you are well away from the edge of the field. Then stop the combine, disengage the platform drive, raise the platform, and back up 15 to 20 feet. Place the frame across the harvested rows behind the combine, and count the loose beans, beans in pods on or off the stalks, and beans on the stubble inside the frame. Divide this figure by 40. The result is the total loss in bushels per acre, and it includes both preharvest and harvest losses. If the loss is near 3 percent of the yield, continue harvesting.

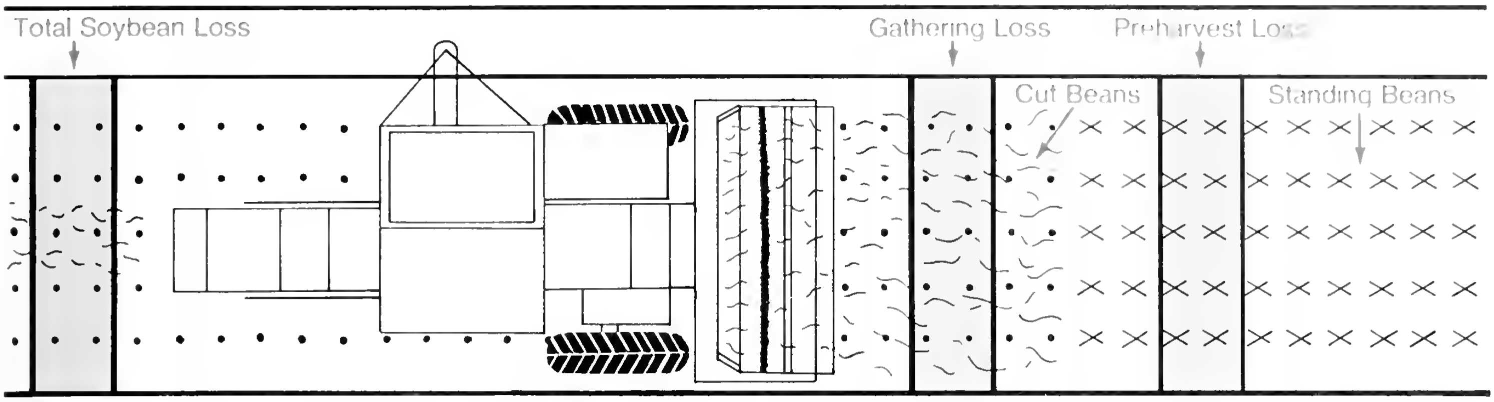
To measure preharvest losses, place the frame across the rows of standing soybeans in front of the combine, count the loose beans and the beans in pods on the ground, and divide by 40. To arrive at the total harvesting loss, subtract the preharvest loss from the total loss found behind the combine.

If your harvesting losses are too high, you should use the following procedure to determine where most of these losses are occurring. First, place the frame across the harvested rows in front of the combine just ahead of the drive-wheel tracks. Count all the beans inside the frame, subtract the number of beans found in the preharvest count, and divide by 40. The result is your gathering loss. When making this count, be sure to note how many of each of the four types of gathering losses there are, so you will know where to make adjustments in the machinery. You can find the cylinder and separating losses by subtracting the gathering losses from the total harvesting losses.

## Reducing Soybean Losses

### *Header Design*

In 1976, University of Illinois researchers conducted a large-plot experiment at Urbana to compare the effects of variety, narrow row spacing, and




The shaded areas in the drawing above show where you should place a frame to measure your total soybean loss, preharvest loss, and gathering loss.

header design upon soybean losses during harvest. Corsoy, Amsoy-71, Beeson, and Williams varieties were grown in row spacings of 7 and 30 inches. The target population was about 170,000 plants per acre for the 7-inch rows and 125,000 for the 30-inch rows. The data in the table at right, top, show the effect of row width and variety upon preharvest loss and yield. In 7-inch rows, the yield of Corsoy increased 8 percent, that of Beeson 4 percent, and Amsoy-71 2 percent compared to their yields in 30-inch rows. Growing Williams in 7-inch rows did not increase its yield.

The table at right, bottom, compares the header losses that occurred when various types of headers were used in 30- and 7-inch soybean rows. Header loss with both types of platform headers was about 30 percent less in 7-inch than in 30-inch rows. In 30-inch rows, the row-crop header proved to be the most efficient type under the conditions of our experiment.

The data we obtained during the 1976 season proved that a floating cutterbar header with air-jet guards reduces harvest losses by 45 percent, compared to a conventional floating cutterbar header. But the flexible floating cutterbar header, either with or without the air-jet guards, is even more efficient. In fact, the air-jet system is probably unnecessary because the addition of it did not significantly increase the harvesting efficiency of the flexible floating cutterbar. This type of header has several features that enable it to reduce soybean losses: its long dividing points help prevent problems that occur in lodged soybeans; its extended platform and low profile reduce shatter and stalk losses; and its large-diameter auger rapidly moves plant material to the center and helps reduce stalk losses.

To determine which header has the most potential for increasing profits, we analyzed the harvesting costs and crop yields with various combine header configurations in 7- and 30-inch row spacings. We used yield and loss data for Corsoy because this variety produced the highest yield in both row

| | Preharvest loss, percent | Yield, bushels per acre |
|---|---|---|
| Amsoy-71 | | |
| 7-inch rows | 1.8 | 45.8 |
| 30-inch rows | 2.2 | 44.9 |
| Beeson | | |
| 7-inch rows | 5.1 | 38.9 |
| 30-inch rows | 4.3 | 37.3 |
| Corsoy | | |
| 7-inch rows | 0.2 | 53.3 |
| 30-inch rows | 0.2 | 49.3 |
| Williams | | |
| 7-inch rows | 1.1 | 37.2 |
| 30-inch rows | 0.4 | 37.7 |

| | Total header loss, percent | Reduction in loss, percent |
|---|---|---|
| Flexible floating cutterbar | | |
| 7-inch rows | 2.4 | 37 |
| 30-inch rows | 3.8 | |
| Flexible floating cutterbar with air-jet guards | | |
| 7-inch rows | 2.4 | 30 |
| 30-inch rows | 3.4 | |
| Floating cutterbar | | |
| 7-inch rows | 6.3 | 28 |
| 30-inch rows | 8.7 | |
| Floating cutterbar with air-jet guards | | |
| 7-inch rows | 3.3 | 33 |
| 30-inch rows | 4.9 | |
| Row-crop header | | |
| 30-inch rows | 1.4 | |

spacings. The study was conducted for an average central Illinois grain farm that had 250 acres of soybeans and 300 acres of corn.

By reducing harvest losses, the row-crop header, in spite of its higher cost, returned $5 per acre more than the flexible floating cutterbar in 30-inch rows. The flexible floating cutterbar, however, returned $25 per acre more in 7-inch rows than the row-crop header in 30-inch rows. The platform header in 7-inch

rows proved more profitable because the yield was 4 bushels per acre higher at that row spacing, the purchase price of that header was lower, and because it held harvest loss to an acceptable level.

In this analysis we assumed that control of weeds was equal in both row spacings, but realized of course that mechanical cultivation is impossible in 7-inch rows. We also assumed that the row-crop header was operated at 5.0 miles per hour (mph) and the flexible cutterbar at 3.5 mph. We did not include a cost factor for the timeliness of harvest operations.

It is obvious from our analysis that under good production management solid-seeded soybeans can be profitably produced. Farm equipment manufacturers have made equipment available that, if used properly, can keep harvest losses below 4 percent, regardless of the row spacing.

## • *Combine Adjustments*

To take full advantage of the time available for harvesting, make all necessary repairs and major adjustments well before the harvest season. Using the operators manual as a guide, thoroughly repair, lubricate, and adjust the combine. Familiarize yourself with the adjustments in the manual and those described here, so that you can make adjustments easily and quickly in the field.

Studies conducted by researchers at The Ohio State University, the University of Illinois, and Iowa State University have proven that to make any major gains in harvesting efficiency, the header must be properly adjusted to reduce gathering losses, particularly shatter, lodged, and stalk losses. The header must cut close to the ground to avoid leaving soybeans on the stubble and shattering them from the stalks. To further reduce shatter losses, it must be able to handle the beans as gently as possible. Rough handling by the header's cross auger and by the slat conveyors in the feeder housing can thresh a substantial percentage of the soybeans before they reach the combine cylinder. These soybeans can be lost if the slope of the header's deck is improperly adjusted, the deck is not tight, or if the plant material is not fed uniformly into the combine cylinder.

Almost all gathering losses are caused by the action of the knife and reel. Keep the knife sharp and replace broken or badly worn sections. Adjust the wear plates to minimize knife vibration. Align the guards and adjust the knife clips, so the knife can move freely and cut efficiently.

Proper reel adjustments are particularly necessary to keep losses low. A pick-up reel can help reduce harvesting losses. The speed of the pick-up reel should be 50 percent greater than ground speed. A 42-inch reel should rotate at about 12 revolutions per minute (rpm) for each 1 mph of forward speed. The reel will shatter soybeans excessively if it turns too fast, but it may drop stalks or allow too many of them to be recut if it turns too slowly.

The reel axle should be 8 to 12 inches ahead of the sickle on most headers. With a pick-up reel and floating cutterbar, the reel axle should be about 8 inches ahead of the sickle. Several manufacturers are now providing headers with a built-in flexible cutterbar. When harvesting short plant material, you may need to move the reel axle nearer the cutterbar.

To prevent excessive threshing and separating losses and still keep the soybeans clean, the threshing and separating mechanisms must be kept properly adjusted.

Probably the single most important item to check is the separator speed. In each combine a particular shaft serves as a starting point for checking the operating speed. In some machines this starting point is the cylinder-beater cross-shaft; in others it is the primary countershaft. Most combines are designed to operate at the proper speed when the speed control lever of the engine is in the maximum position. If the separator is not running at the proper speed with the control lever in this position, adjustment is needed.

If you are not certain of the procedure for adjusting engine speed, check the operators manual or have the work done by your local dealer. A small deviation from the correct engine speed can affect the operation of the cleaning and separating units, making it impossible to get soybeans clean and keep losses to a minimum.

Before taking the combine to the field, you should adjust, in addition to the cylinder speed, the cylinder-concave clearance, the sieve settings, and the speed and opening of the cleaning fan. If you follow the operators manual closely in making these adjustments, you should have to make only minor adjustments in the field.

For most conventional combines, the recommended cylinder-concave clearance for soybeans is 3/16 to 3/8 inch at the back and 3/8 to 1 inch at the front. The cylinder and fan speed must be adjusted to fit your threshing conditions. When the moisture content of the soybeans is above 13 percent, they are usually tough, so the cylinder speed may have to be increased to 600 to 650 rpm. As soybeans dry, lower the cylinder speed to reduce breakage; 450 to 500 rpm should be high enough for soybeans that are below 13 percent in moisture content.

## • *Rotary Combines*

One way to improve the quality of soybeans is to reduce the mechanical damage caused by the combine threshing mechanism during harvesting.

Efforts to reduce threshing damage while increasing capacity have resulted in the development of rotary threshing equipment. Rotary combines have one or more rotors, instead of the conventional cylinder and straw walkers, for threshing and separating grain from crop material. The crop material is swirled around the rotor and passes over concaves several times. The threshing action of the rotor is reported to be more gentle than that of the cylinder.

New Holland was the first company to introduce the concept of rotary, or axial-flow, threshing with its TR-70 combine. International Harvester followed with its single-rotor, axial-flow combine. In 1978 Allis-Chalmers introduced its N-Series rotary combine, and in 1979 White introduced its Model 9700 axial-flow combine. It appears that the rotary combines are here to stay. But in spite of the popularity of these new combines, the conventional cylinder combines will probably be around for a long time.

A study was conducted at the University of Illinois in 1977 to determine the damage to soybeans caused by rotary and conventional threshing mechanisms. In this study an International 1460 Axial-Flow (single-rotor) combine, a Sperry New Holland TR-70 (double-rotor) combine, and John Deere 7700 (conventional rasp-bar-cylinder) combine were tested under field conditions. The quality of the harvested soybeans was evaluated, and the threshing and separating losses for each combine were determined. All three combines were equipped with 20-foot-wide, floating cutterbar headers.

The results of the study, which are summarized in the following paragraphs, pertain only to the particular combines and soybean variety (Amsoy-71) tested in this study and to the particular conditions under which the study was conducted.

The percentage of soybean splits was significantly higher for the conventional cylinder than for the single- or double-rotor threshing mechanisms at similar peripheral threshing speeds. However, when the mechanisms were operated within the range of cylinder or rotor speeds recommended by the respective manufacturers, the percentage of splits did not exceed the allowable 10 percent limit for U.S. No. 1 grade soybeans.

With all three mechanisms, the percentage of splits increased as the peripheral threshing speed of the cylinder or rotor was increased. The increase in splits was less with the rotary threshing mechanisms than with the conventional cylinder, as shown in the graph at right.

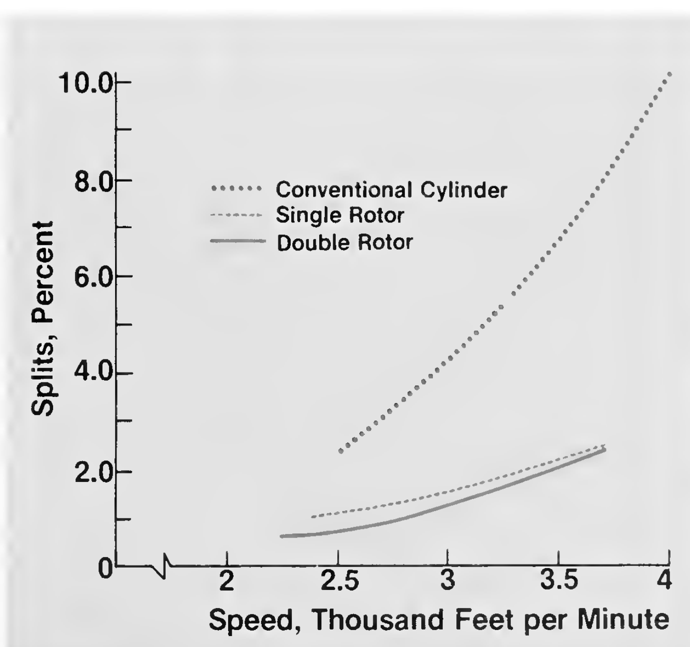
With all three mechanisms, threshing and separating losses decreased as the cylinder or rotor speed was increased. These losses ranged from 0.2 to 0.5 percent of yield. With the rotary combines they were significantly higher at the lowest rotor speed than at the higher speeds.

Increasing the concave clearance generally decreased the percentage of splits for all three combines, although this adjustment had less effect than changes in cylinder or rotor speed. The percentage of splits was not significantly affected by concave adjustment until after a minimum clearance was reached for the rotary combines.

The susceptibility of soybeans to breakage and the seed-coat crack percentage were not affected significantly by the type of threshing mechanism or the cylinder or rotor speed. Nor did these factors affect other criteria used in grain-inspection grading, such as test weight, percentage of damaged kernels, and percentage of foreign material.

We found that improvements were needed in the design of augers and elevators that convey soybeans from the clean-grain auger to the grain tank. The percentage of splits that occurred as soybeans were elevated from the clean-grain auger to the grain tank averaged 1.0 percent for the conventional cylinder, 0.6 percent for the single-rotor, and 1.4 percent for the double-rotor combines.

The results of studies at The Ohio State University and the University of Illinois indicate that adjustments to rotary combines may be less critical than those to conventional rasp-bar-cylinder combines. However, the results of these studies also indicate that during threshing and cleaning a properly adjusted conventional combine can keep soybean damage well below the level that leads to dockage.




The effect of cylinder or rotor threshing speed on the percentage of splits in clean grain auger samples.

### *Weeds*

Although it has long been recognized that weeds are detrimental to soybean production, only in recent years has their effect on combine harvesting efficiency been studied. University of Illinois researchers conducted experiments at Urbana, Illinois, in 1968 and 1969 to determine the effect of controlled infestations of smooth pigweed and giant foxtail upon soybean yields and harvesting losses.

In these experiments the smooth pigweed infestation (one pigweed per foot of row) reduced the average yield 25 to 30 percent. The same degree of giant foxtail infestation reduced yield 13 percent. But the weeds did not cause significant losses at the header during harvest as long as the weeds were desiccated before harvest began. The results of the experiment also indicate that harvesting soybeans before frost has desiccated the weeds results in excessive threshing and separating losses unless the ground speed of the combine is reduced. In some pigweed infested plots, 4.4 percent of the crop was lost during threshing and separating when it was harvested at 3 mph, whereas only 0.7 percent was lost when ground speed was reduced to 1 mph. At both speeds about 1 percent of the crop was lost during threshing and separating when it was harvested after the pigweed had dried.

### *Population and Row Spacing*

University of Illinois researchers conducted experiments at Urbana, Illinois, in 1969, 1970, and 1971 to determine the effect of population, row spacing, and cultivation upon soybean yields and harvest losses. Amsoy variety was grown in 1969 and 1970 and Beeson in 1971. The results of these experiments are presented in the table on page 59.

In 1969, the experimental plots were harvested with a standard header, which left stubble about 4 inches high. The height of the stubble was only about 2½ inches in the 1970 experiments. In that year, the combine was equipped with a floating cutterbar. In 1971, a combination floating cutterbar and finger height control was used that left the stubble about 3 inches high. The floating cutterbar reduced the height of the stubble and, as shown in the table, lowered stubble and lodged losses considerably. This attachment also reduced shatter losses somewhat. Fewer pods were shattered by the cutterbar because of the lower stubble.

Population and row spacing did not affect yield significantly over the three-year period. Plant populations as low as 100,000 plants per acre produced yields comparable to those of the higher rates. But because higher populations tended to increase lodging, they resulted in higher header losses, especially in the 30-inch rows that were not cultivated. For example, in 1971 total header loss reached 8.99 percent in the high-population plots planted in 30-inch rows, but it was only 4.43 percent in the low-population plots.

Although heavy cultivation in the 30-inch rows reduced lodging, it increased harvest losses because plant material was cut and lost between the ridged rows. Heavy cultivation in these rows also increased stalk and shatter loss. You will notice, for example, that in 1970 total header loss was 4.88 percent in the uncultivated 30-inch rows with low plant population but 9.90 percent in the cultivated 30-inch rows.

The most significant reduction in total header loss occurred in the 8-inch rows when the population was increased from 100,000 plants per acre to 170,000 plants (we have data from only one year to support this finding). The higher population increased competition for sunlight, which in turn increased podding height. As a result, shatter loss dropped from 4.30 percent to 2.03 percent, and stalk loss dropped from 2.96 percent to 1.25 percent. A further increase in population to over 200,000 plants per acre caused shatter loss to drop to 1.75 percent. But the higher population resulted in weaker plant stems, pushing lodged loss up to 2.78 percent. It is apparent that if you grow the varieties tested in this study, or varieties similar to them, you should probably choose a plant population in the middle range shown in the table to keep header losses down to an acceptable level in narrow rows.

## Drying and Storage

Soybeans need to be drier than corn or wheat before they can be stored safely under similar conditions. University of Illinois studies have shown that soybeans having a moisture content of 10 percent or less remain in generally good condition up to four years. Market-grade soybeans with a moisture content of about 12 percent retain their grade for nearly three years, although germination and other qualities of the seed gradually decline over that period. Seed that has a moisture content of 13 percent can be safely stored only from harvest to late spring. If its moisture content is 14 percent, the safe period is limited to the winter months. Soybeans having a moisture content of 15 percent or more usually should not be stored without drying.

Soybeans normally require artificial drying only during wet seasons. The weather in fall is usually such that field drying is sufficient. Some farmers, however, have turned to drying to increase the number and length of days available for harvesting. You may gain a few days during the harvesting season if you begin harvest when the moisture content of the soybeans reaches 18 to 20 percent and later

**Effect of Population, Row Spacing, and Cultivation on Soybean Yield and Harvest Losses, 1969-1971**

| Population, thousands of plants per acre | Row spacing, inches | Preharvest loss, percent | Header losses, percent | | | | | Threshing and separating loss, percent | Total loss, percent | Total yield, bushels per acre |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Shatter | Stubble | Lodge | Stalk | Total | | | |
| **1969** | | | | | | | | | | |
| Low | 15 | 0.09 | 3.91 | 2.92 | 0.32 | 1.16 | 8.31 | 0.73 | 9.13 | 54.4 |
| (105-126) | 30 | 0.04 | 2.98 | 0.78 | 0.06 | 1.26 | 5.08 | 0.33 | 5.45 | 53.9 |
| | 30C* | 0.10 | 3.19 | 1.68 | 0.74 | 2.02 | 7.63 | 0.30 | 8.03 | 58.9 |
| Medium | 15 | 0.11 | 4.03 | 1.69 | 0.56 | 1.23 | 7.51 | 0.39 | 8.01 | 54.5 |
| (146-174) | 30 | 0.03 | 2.77 | 0.71 | 0.30 | 0.96 | 4.74 | 0.35 | 5.12 | 54.2 |
| | 30C | 0.08 | 3.08 | 0.92 | 0.42 | 0.99 | 5.41 | 0.24 | 5.73 | 52.4 |
| High | 15 | 0.07 | 2.62 | 1.31 | 0.45 | 1.05 | 5.43 | 0.71 | 6.21 | 53.1 |
| (178-206) | 30 | 0.05 | 2.13 | 2.76 | 0.59 | 1.14 | 6.62 | 0.35 | 7.02 | 52.6 |
| | 30C | 0.09 | 3.33 | 1.32 | 0.72 | 1.26 | 6.63 | 0.19 | 6.91 | 52.3 |
| **1970** | | | | | | | | | | |
| Low | 15 | 0.29 | 2.14 | 0.30 | 0.95 | 3.47 | 6.86 | 0.32 | 7.47 | 61.6 |
| (58-67) | 30 | 0.28 | 1.39 | 0.31 | 0.30 | 2.88 | 4.88 | 0.12 | 7.28 | 57.4 |
| | 30C | 0.38 | 2.56 | 0.23 | 0.54 | 6.57 | 9.90 | 0.13 | 10.41 | 58.6 |
| Medium | 15 | 0.58 | 2.39 | 0.01 | 0.07 | 4.53 | 7.00 | 0.36 | 7.94 | 59.6 |
| (108-156) | 30 | 0.38 | 1.81 | 0.02 | 0.11 | 2.64 | 4.58 | 0.09 | 5.05 | 59.4 |
| | 30C | 0.45 | 2.28 | 0.00 | 0.21 | 5.43 | 7.92 | 0.10 | 8.47 | 57.7 |
| High | 15 | 0.36 | 1.97 | 0.03 | 0.15 | 3.28 | 5.43 | 0.15 | 5.94 | 60.4 |
| (167-180) | 30 | 0.28 | 2.12 | 0.00 | 0.17 | 3.15 | 5.44 | 0.16 | 5.88 | 57.3 |
| | 30C | 0.73 | 1.43 | 0.08 | 0.45 | 4.91 | 6.87 | 0.12 | 7.72 | 57.3 |
| **1971** | | | | | | | | | | |
| Low | 8 | 0.14 | 4.30 | 0.00 | 0.00 | 2.96 | 7.26 | 0.67 | 8.07 | 49.1 |
| (95-113) | 15 | 0.22 | 2.47 | 0.00 | 0.07 | 3.71 | 6.25 | 0.54 | 7.01 | 46.5 |
| | 30 | 0.23 | 2.50 | 0.00 | 0.00 | 1.93 | 4.43 | 1.22 | 5.88 | 48.5 |
| Medium | 8 | 0.36 | 2.03 | 0.00 | 0.00 | 1.25 | 3.28 | 1.10 | 4.74 | 50.0 |
| (170-205) | 15 | 0.17 | 2.39 | 0.00 | 0.00 | 1.92 | 4.31 | 1.14 | 5.62 | 49.6 |
| | 30 | 0.35 | 2.57 | 0.00 | 0.02 | 2.82 | 5.41 | 1.24 | 7.00 | 41.8 |
| High | 8 | 0.07 | 1.75 | 0.00 | 0.01 | 2.78 | 4.54 | 1.52 | 6.13 | 45.5 |
| (220-305) | 15 | 0.26 | 3.15 | 0.00 | 0.08 | 2.36 | 5.59 | 1.70 | 7.55 | 46.9 |
| | 30 | 0.43 | 2.90 | 0.00 | 0.24 | 5.85 | 8.99 | 2.53 | 11.95 | 46.2 |

* Cultivated treatment.

aerate the grain to reduce its moisture content to a level that is safe for storage. Keep in mind, however, that some varieties are more susceptible than others to damage at harvest when the moisture content is high. Harvesting under those conditions usually reduces header losses, but the reduction may be offset somewhat by increased losses in the combine. To get the maximum benefit of harvesting high moisture soybeans, be sure you obtain complete threshing and keep unthreshed pods out of the grain tank.

Because high moisture soybeans are not safe for storage, drying facilities are an essential part of the harvesting and storage system. Studies at The Ohio State University indicate that to avoid seed-coat cracking when drying soybeans you must keep the humidity of the drying air above 40 percent. Soybeans for seed should not be dried at temperatures above 110° F. Most often, the maximum temperatures recommended are 130° to 140° F. At these higher drying temperatures, splits can become a critical problem, and soybean handling can cause excessive seed damage.

Cooling the grain reduces respiration and the activity of mold and insects. You should cool soybeans by means of aeration after placing them in the storage bin. A properly designed aeration system should be able to move air through the grain at a rate of about 1/10 cubic foot per minute per bushel. You should cool the grain anytime the temperature of the grain mass is 10° F. above the outside air temperature. But you should not reduce the temperature of the grain below 35° to 40° F. Using drying fans (with the heater off) to force air up through the grain, you can aerate the grain in three or four hours. A properly designed and installed aeration system can eliminate the need for turning the grain or moving it if it gets hot because of respiration.

# Moisture Management

An important means of increasing soybean yields is to improve moisture management. By eliminating moisture stress, you will be better able to obtain the benefits of improved cultural practices and realize the genetic potential of the soybean varieties now available.

To produce maximum yields, the soil must be able to provide water as it is needed by the soybean plant. But the soil seldom has just the right amount of water for maximum crop production. Usually, there is either a deficiency or a surplus. A good moisture management program seeks to avoid both extremes through a variety of measures. These include draining waterlogged soils; making more effective use of the water-holding capacity of soils, so that crops will grow during periods of deficient rainfall; increasing the soil's ability to absorb moisture and conduct it down through the soil profile; reducing the loss of moisture from the soil surface; and perhaps diverting, harvesting, and storing water (either in surface impoundments or underground) during periods of excessive rainfall, so that it can be used for irrigation during dry seasons.

## Drainage

Excess water in the soil limits the amount of oxygen available to plants and as a result retards their growth. This problem occurs where there is either a high water table or ponding of water on the soil surface. Removing this excess water from the root zone is an important first step toward a good moisture management program. A drainage system should be capable of removing water from the soil surface and lowering the water table to about 12 inches beneath the soil surface in 24 hours and down to 21 inches in 48 hours.

### The Benefits of Drainage

By installing a well-planned drainage system, you can derive a number of benefits: better soil aeration, more time for performing field operations, less flooding in low areas, higher soil temperatures, less surface runoff, better soil structure, better incorporation of herbicides, better root development, higher yields, and improved crop quality.

**Soil aeration.** Good drainage ensures that roots and microorganisms in the soil receive enough oxygen

to develop properly. When the soil becomes waterlogged, aeration is impeded, causing a decrease in the amount of oxygen available. Oxygen deficiency reduces root respiration and often the total volume of roots developed. It also increases resistance to the transport of water and nutrients through the roots. The roots of most nonaquatic plants are injured by oxygen deficiency. Prolonged oxygen deficiency may result in the death of some cells, entire roots, or in extreme cases the whole plant.

**Timeliness.** Because a good drainage system increases the number of days available for planting and harvesting, it can enable you to make more timely field operations. It can reduce the likelihood that planting will be delayed and that good crops will be drowned out or left standing in fields that are too wet for harvest. Good drainage may also reduce the need for the additional equipment that is sometimes necessary where fields remain wet for long periods and fewer days are available for field operations.

**Soil temperature.** Drainage can increase the temperatures at the surface of the soil during the early months of the growing season by 6° to 12° F. Warmer temperatures assist germination and increase plant growth.

**Surface runoff.** By better enabling the soil to absorb and store rainfall, drainage reduces runoff of water from the soil surface and as a result reduces soil erosion.

**Soil structure.** Good drainage is essential in maintaining the structure of the soil. Without adequate drainage the soil remains saturated, causing the normal wetting and drying cycle and the corresponding shrinking and swelling of the soil to cease. The structure of the saturated soil will suffer further damage if you perform tillage or harvesting operations on it.

**Herbicide incorporation.** Good drainage can help you avoid costly delays in herbicide application, particularly of postemergence herbicides. These herbicides must sometimes be applied while the weeds are still relatively small. Since the weeds remain so for only a short period, you may not be able to make a timely application unless you have an adequate drainage system that keeps the soil dry enough for field operations. Drainage may also help relieve the cool, wet stress conditions that make crop injury by some herbicides more severe.

**Root development.** Good drainage enables plants to send roots deeper into the soil, so they can extract moisture and plant nutrients from a larger volume of soil. Plants that have deep roots are better able to withstand drought.

**Crop yield and quality.** All these benefits contribute to greater yields of higher quality crops. The exact amount of the increase in yield and quality depends on the type of soil, the amount of rainfall, the fertility of the soil, the crop management practices you use, and the level of drainage before and after improvements are made.

So far, only a few studies have been conducted to determine the benefits of drainage for soybeans in precise, economic terms. One study, which was conducted by specialists at The Ohio State University from 1976 to 1979, compared the effects of different drainage methods on soybean yields in Toledo silty clay soil. This soil is poorly drained and has a heavy, impermeable subsoil. Each test plot was given one of four treatments: no drainage, surface drainage, subsurface drainage, or a combination of surface and subsurface drainage. All the subsurface drains were placed 3 feet deep and 40 feet apart. Irrigation water was applied twice during most of the four years of the study to simulate heavy rainfall. The four-year average soybean yields were 35 bushels for the undrained plots, 43 bushels for the surface-drained plots, 49 bushels for the subsurface-drained plots, and 52 bushels for the plots that were both subsurface and surface drained.

In another study on the same soil type, researchers at The Ohio State University further examined the effect of various levels of drainage on soybeans. They found that on undrained plots the crop stand was sparse and there was almost no growth. Water formed ponds on these plots and remained for long periods. The surface of the soil became crusted, and it was obvious that the structure of the soil had been badly damaged. Among the plots that did have some type of drainage, there was no measurable difference in soybean stand or in the amount of crusting that occurred in the surface layer of the soil. The plots that had subsurface drainage or a combination of surface and subsurface drainage retained less moisture, were less resistant to surface penetration, were less crusty, and produced taller plants, better developed root systems, and greater yields than plots that had surface drainage alone.

## Drainage Methods

A drainage system may consist of surface drainage, subsurface drainage, or some combination of both. The kind of system you need depends in part upon the ability of the soil to transmit water.

### • *Surface Drainage*

A surface drainage system is most appropriate on flat land having slow infiltration and low permeability and on soils with restrictive layers close to the surface. With this type of system, excess water

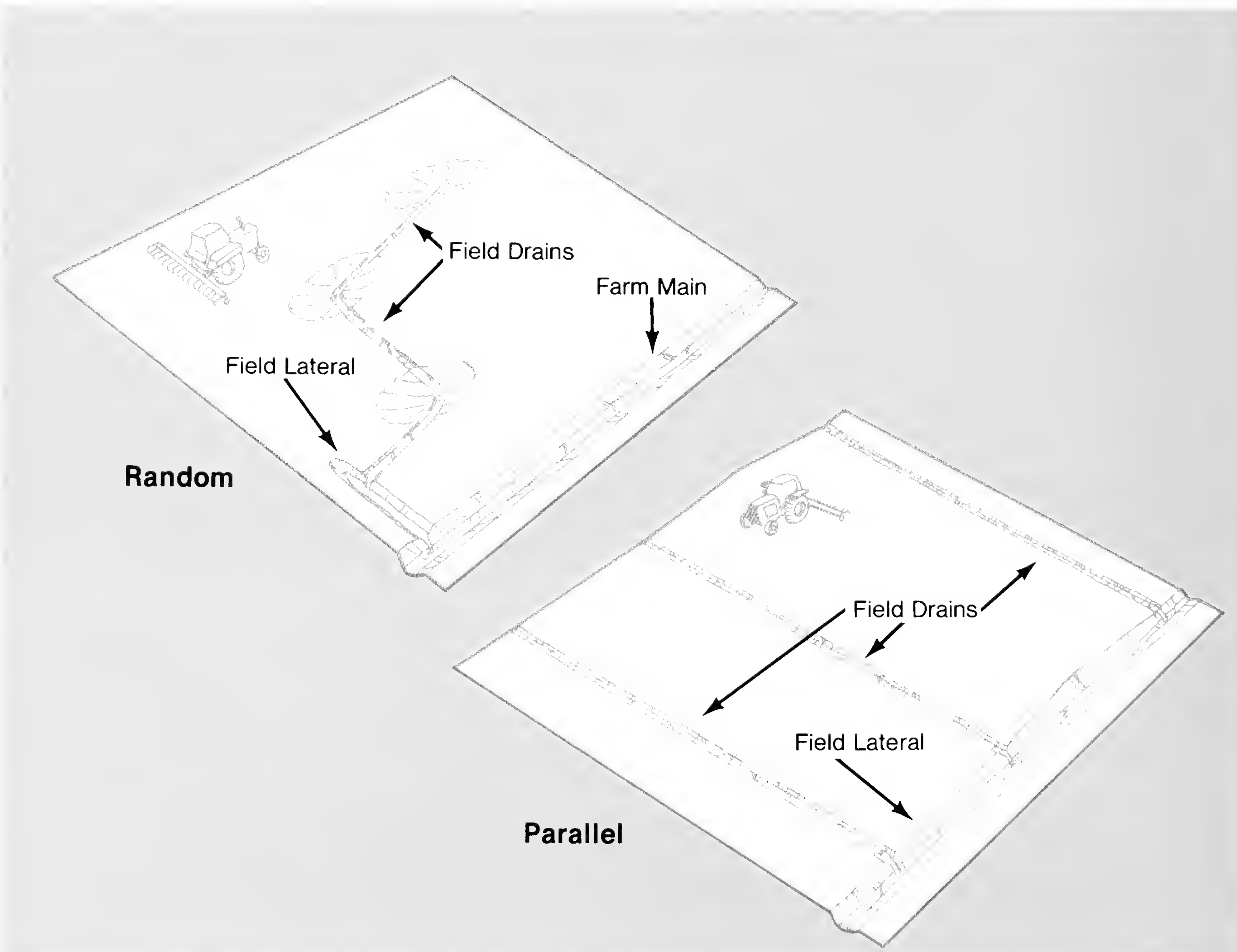
is removed from the soil surface through improved natural channels or man-made ditches and through shaping of the surface of the land. A properly planned system eliminates ponding, prevents prolonged saturation, and accelerates the flow of water to an outlet without permitting siltation or soil erosion.

A surface drainage system consists of a farm main, field laterals, and field drains. The farm main is the outlet serving the entire farm. Where soil erosion is a problem, it may be desirable to let a surface drain or waterway covered with vegetation serve as the farm main. Field laterals are the principal ditches that drain adjacent fields or areas on the farm. The laterals receive water from field drains or sometimes from the surface of the field and carry it to the farm main. Field drains are shallow, graded channels with relatively flat side slopes; these drains collect water within a field.

Two other components that are sometimes included in a surface drainage system are diversions and interceptor drains. Diversions are channels constructed across the slope of the land to intercept surface runoff and prevent it from overflowing bottomlands. These channels are usually located at the base of a hill. Diversions simplify and reduce the cost of drainage for bottomlands.

Interceptor drains are channels installed to collect subsurface flow before it resurfaces. These channels may also collect and remove surface water. They are used on long slopes that have 1 percent or steeper grades and on shallow, permeable soils overlying relatively impermeable subsoils. The location and depth of these drains are determined from soil borings and the topography of the land.

The principal types of surface drainage systems are the random and parallel systems (see the drawings below). The **random system** is made up of meandering field drains that connect the low spots in a field and provide an outlet for excess water. This system is adapted to slowly permeable soils having




Types of surface drainage systems.

depressions that are too large to be eliminated by smoothing or shaping of the land.

The **parallel system** is suitable for flat, poorly drained soils that have numerous shallow depressions. In a field that is cultivated up and down its slope, parallel ditches can be placed so as to break the field into shorter lengths. The excess water thus erodes less soil because it flows over only a relatively small part of the field surface before reaching a ditch. The side slopes of the parallel ditches should be flat enough to permit farm equipment to cross. The spacing of the parallel ditches will vary according to the slope of the land.

For either the random or parallel systems to be fully effective, you must eliminate minor depressions and irregularities in the soil surface through land grading or smoothing.

**Bedding** is another surface drainage method that is occasionally used. The land is plowed to form a series of low, narrow ridges separated by parallel, dead furrows. The ridges are oriented in the direction of the steepest slope in the field. Bedding is adapted to the same conditions as the parallel system. However, bedding interferes more with farm operations, and it does not drain the land as completely. Under most conditions, it is not suitable for land planted in row crops because rows adjacent to the dead furrows will not drain satisfactorily. Bedding is acceptable for hay and pasture crops, although it will cause some crop loss in and adjacent to the dead furrows.

## • *Subsurface Drainage*

A subsurface drainage system is used in soils that are permeable enough that the drains do not have to be placed too close together. If the spacing is too narrow, the system will not be economical. The soil must also be productive enough to justify the investment. Further, since a subsurface drainage system functions only as well as the outlet, you must make sure that a suitable outlet is available or that one can be made. Consider too the topography of your fields, keeping in mind that the installation equipment has depth limitations and that a minimum amount of soil cover is required over the drains.

Subsurface systems are made up of an outlet or main, sometimes a submain, and field laterals. The drains are placed underground, although the outlet is often a surface drainage ditch. Subsurface drainage conduits are constructed of clay, concrete, or plastic.

There are four types of subsurface systems: the random, herringbone, parallel, and double-main systems (see the drawings on page 64). You may need either a single system or some combination of systems. Choose the one or ones that best fit the topography of your land.

For rolling land, you should plan to have a **random system** installed. With this system, the main drain is usually placed in a depression. If the wet areas are large, the submains and lateral drains for each area may be arranged in a gridiron or herringbone pattern to provide the required drainage.

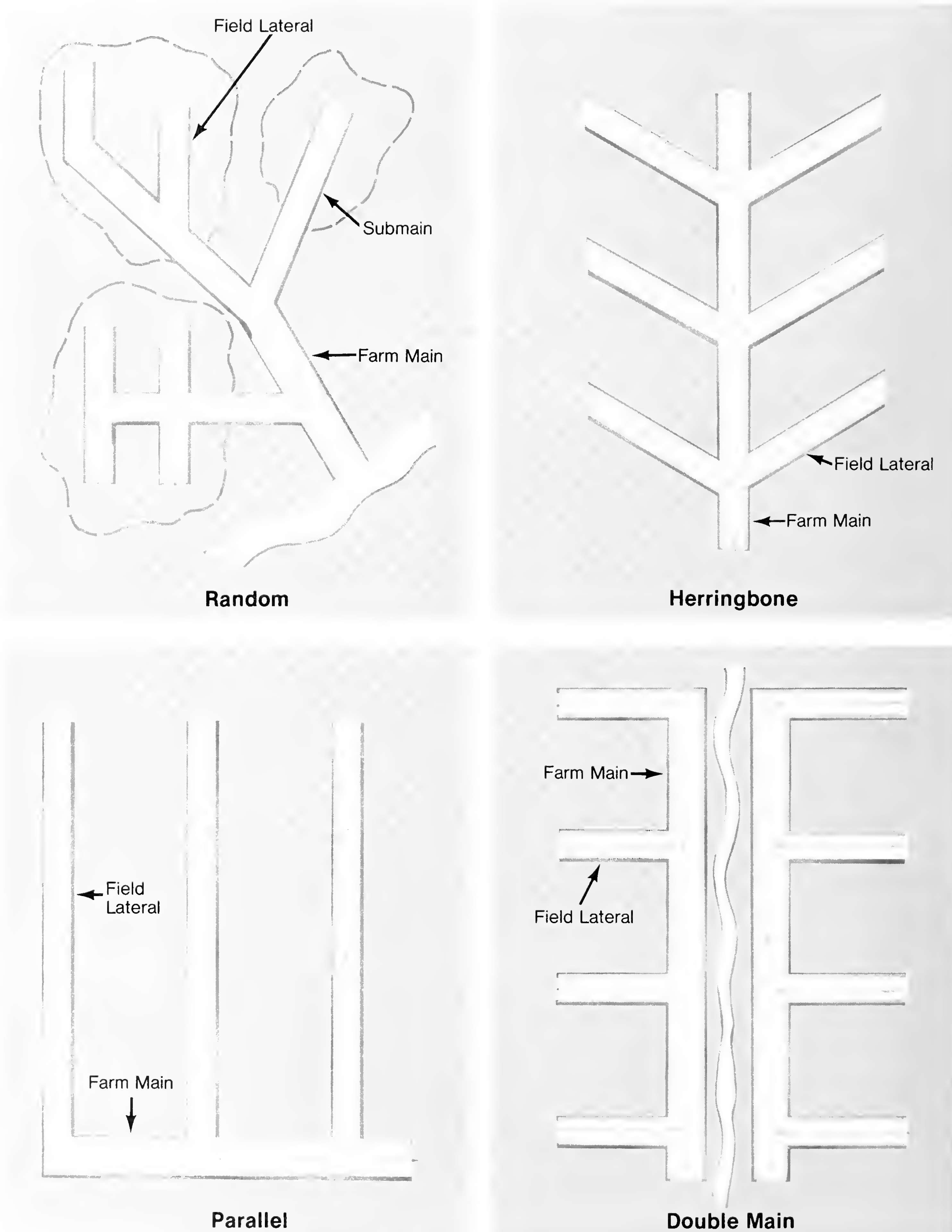
With the **herringbone system,** the main or submain is often placed in a narrow depression. The main may also be located on the major slope of the land. The lateral drains are angled upstream on either side of the main. This system is sometimes combined with other systems to drain small or irregular areas. One of its disadvantages is that because two laterals intersect the main at the same point there may be more drainage than is necessary at that point. This system may also cost more since it requires more junctions. Nevertheless, it can provide the extra drainage needed for the heavier soils that are found in narrow depressions.

The **parallel system** is similar to the herringbone system, except that the laterals enter the main from only one side. This system is used on flat, regularly shaped fields and on uniform soil. Variations of it are often used with other patterns.

The **double-main system** is a modification of the parallel and herringbone systems. It is used where a depression, frequently a natural watercourse, divides the field in which drains are to be installed. Sometimes the depression may be wet because of seepage from higher ground. A main is placed on each side of the depression to intercept the seepage water and provide an outlet for the laterals. If only one main were placed in the center of a deep and unusually wide depression, it would be necessary to change the grade of each lateral at some point before it reaches the main. With a double-main system, you can avoid this situation and keep the gradelines of the laterals uniform.

The advantage of a subsurface drainage system is that it usually drains soil to a greater depth than surface drainage. Subsurface drains placed 48 inches deep and 80 to 100 feet apart are suitable for soybean production on many medium textured soils in Illinois. When properly installed, these drains require little maintenance, and because they are underground, they do not obstruct field operations.

For more specific information on surface and subsurface drainage systems for soybeans, obtain the *Drainage Guide for Illinois* from your county Extension adviser. This publication discusses the planning, design, installation, and maintenance of drainage systems for a wide variety of soil, topographic, and climatic conditions.



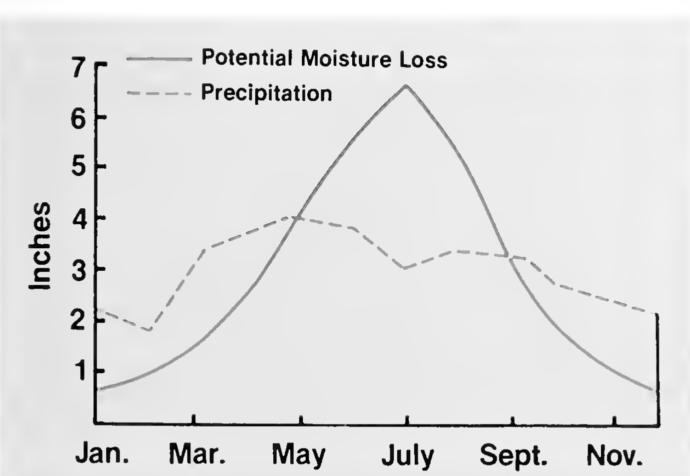

Types of subsurface drainage systems (the arrows indicate the direction of water flow).

# Irrigation

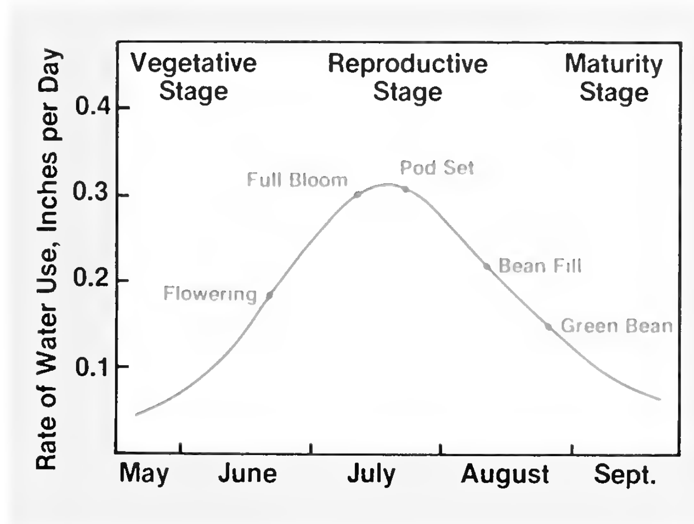
Many regions receive ample rainfall during the year for growing crops, but as shown in the graph below the rain or snow does not occur when the crops need it most. During the growing season, soybeans grown on deep, fine-textured soils may be able to draw upon moisture stored in the soil, assuming that the normal amount of rainfall is received throughout the year. But if rainfall is seriously deficient or if the soil has little capacity for holding moisture, soybean yield may be reduced. Yield reductions are likely to be most severe on sandy soils or soils with claypans. Claypan soils restrict root growth, and both types of soils are often unable to provide adequate moisture during the growing season.

To prevent moisture stress during the growing season, more and more producers are using irrigation. Irrigation may be appropriate where moisture stress could substantially reduce crop yields and where a supply of useable water is available at a reasonable cost. Although in the United States irrigation is still most widely used in the arid and semiarid states, it can be beneficial in more humid states such as Illinois. Almost every year, drought limits soybean yields to some degree in Illinois, even though the total annual precipitation exceeds the amount of moisture lost through evaporation and transpiration.

Irrigation is currently increasing at a greater rate in the more humid states than in the more arid states of the country. In Illinois a higher percentage of the irrigated land is planted in soybeans than in any other state except Missouri. About 20 percent of Illinois's irrigated land is planted in soybeans, which is an increase of 16 percent since 1966. No doubt, a major reason for this increase is that farmers have begun to realize how seriously moisture stress can limit soybean yield.




Average monthly precipitation and potential moisture loss from a growing crop in central Illinois.



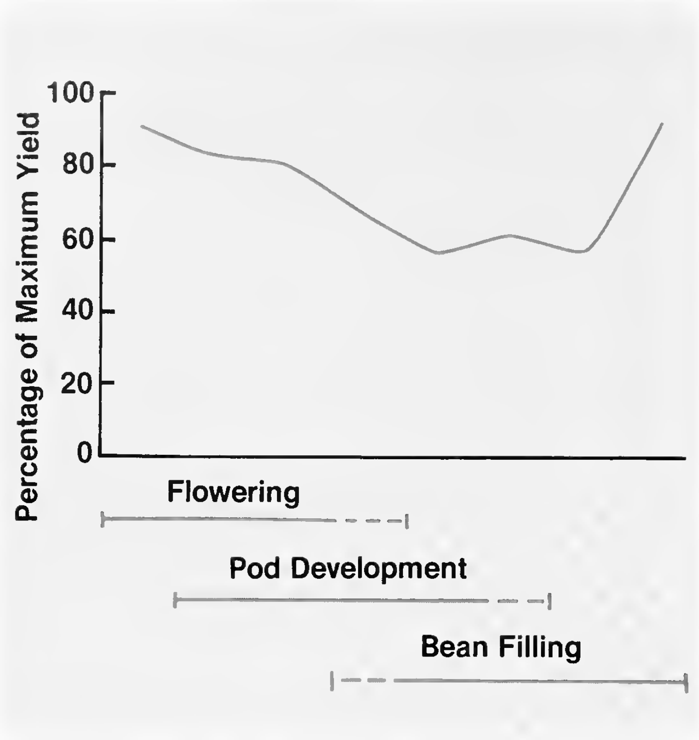

Amount of moisture used by the soybean crop throughout the growing season (adapted from *Soybean Handbook*, Cooperative Extension Service, Kansas State University).

## Irrigation Scheduling

To prevent excessive moisture stress, you should make certain that the soil has the proper amount of moisture at the proper time. The amount of moisture a soybean crop uses throughout the growing season is shown in the graph above. You will notice that the crop uses relatively little moisture at planting and shortly afterwards. It must have just enough moisture during this period to ensure good seed germination and a satisfactory stand. If that amount of moisture is present, it should support the seedlings for a number of days. Moisture stress is typically less likely at planting than at other times because the temperature is usually low and little moisture is lost from the soil.

Under some conditions, however, it may be profitable to irrigate within a few days after planting. For example, irrigation may be necessary in coarse sands because they have little capacity for holding moisture and tend to crust badly. If these soils do not have adequate amounts of moisture, the small seedlings may be cut by blowing sand in windy weather. Irrigation may also be necessary soon after planting if soybeans are used as a double crop following a small grain. Soybeans are particularly vulnerable to moisture stress under these circumstances because the temperature and rate of moisture loss are higher than they are just after spring planting. If moisture loss delays germination or the beginning of vegetative growth, yield may be reduced at least as much as if planting were delayed.

Of the 20 to 30 inches of water that a soybean crop uses each year, 60 to 70 percent is required during the 60-day period that starts about 40 days after soybean emergence. Although there is no single period between emergence and pod set dur-




The effect on soybean yield of visible moisture stress symptoms. Moisture stress can have an especially serious effect during late pod development or early in the bean filling stage, reducing yield by as much as 40 percent (adapted from R. H. Shaw and D. R. Laing, "Moisture Stress and Plant Response," in *Plant Environment and Efficient Water Use*).

ing which adequate moisture is especially critical, there should be enough moisture throughout this period to promote steady, rapid growth of vegetation. Development of the soybean canopy must be complete by pod set, so that the crop will be able to intercept the maximum amount of light at that stage of soybean development.

During the vegetative stage, determinate soybean varieties are much more likely to require irrigation than indeterminate varieties. The latter, if they receive too much moisture during the vegetative stage, may lodge severely. In fact, they may benefit from some moisture stress. The determinate varieties, though, are much less able to tolerate moisture stress because they cease vegetative growth when flowering begins. If they are under severe moisture stress before flowering, the crop canopy may not develop sufficiently by pod set. To ensure complete cover by the crop canopy, it may be best to plant determinate varieties in narrow rows.

During flowering, soybeans are better able than corn to recover from moisture stress because they flower over a longer period. If an unusually high proportion of the soybean flowers abort because of unfavorable conditions, other flowers will be produced and set seed when conditions become more favorable. Under the best conditions, only about a fourth of the flowers set pods. But if severe moisture stress occurs during pod set, pods that are beginning to fill can still abort.

This period is critical in determining seed yield, which is the number of seeds multiplied by the weight per seed. The number of seeds per pod is determined over a relatively short period in the early stage of pod development. The weight per seed depends on the growing conditions during the remainder of the season. Although no single week during the bean filling stage is critical, the seed will not achieve maximum weight if the crop is under moisture stress over a long period. In fact, the results of research conducted by Iowa State University specialists indicate that as few as four consecutive days of visible moisture stress during the pod set and bean filling stages can reduce soybean yield as much as 40 percent (see the graph at left). Irrigation should continue late enough in the the season to prevent serious moisture stress until the leaves begin to turn yellow.

## Irrigation Systems

Your irrigation equipment must be ready for use whenever moisture stress develops, and it must be capable of covering the entire field before the first segment you irrigated comes under moisture stress again. Because hand-move systems require much management and labor, mechanized systems are becoming increasingly popular. Although these systems do not eliminate all the hard work that must go into irrigation, they do reduce the management and labor requirements.

In recent years dramatic advances have been made in irrigation technology. At present, surface application systems are more popular in the arid regions of the country, where larger amounts of water are required each year. The water is usually obtained from large reservoirs built by government agencies or farmers' organizations. The unit cost of this water is usually relatively low.

The systems that are gaining popularity most rapidly are the overhead irrigation systems. They require little labor and are almost always in place and ready for use. The most effective of these systems are the center-pivot, lateral-move, traveling-gun, and solid-set systems. The solid-set systems are probably the easiest to operate, but they also require the largest initial investment. The center-pivot and lateral-move systems, which in recent years have been gaining popularity more rapidly than the others, are almost as easy to operate as the solid-set system. If there is an adequate supply of water, any of these systems can apply water at a

rate no less than that at which it is lost from the growing crop. If managed properly, these systems can prevent detrimental moisture stress.

The overhead irrigation systems work particularly well on fields where reduced tillage is practiced. The crop residue left on the soil reduces the impact of irrigation water and rainfall, thus promoting greater infiltration of water into the soil and reducing soil loss. However, on soils with aeration problems and in which drainage is impeded, the crop residue may only intensify these problems. Because the residue slows the rate at which these soils dry and keeps the soil temperature lower, it may cause a delay in spring planting.

In 1979 about 60 percent of the systems used in Illinois were center-pivot systems. During that year the cost of a center-pivot system, plus the well, pump, gearhead, and power source, was approximately $400 per irrigated acre. The annual capital and operating costs totaled about $100 per acre. Although other types of systems may require less initial capital investment, they often cost more in labor, so that their total cost may be only slightly lower than that of the center-pivot system. Under some conditions — for example, if your fields are irregularly shaped — you may find other systems preferable to the center-pivot system.

To obtain the maximum benefit from any irrigation system, you should irrigate only the acreage the system is capable of covering adequately, even if you have to leave some areas unirrigated. Suppose, for example, that your irrigation system is designed to apply 2 inches of water to 100 acres in a week and that water is lost from the crop at a rate of 2 inches per week. If you use the system on a 100-acre field one week and on another field the next week, the crops in neither field may benefit much, especially if moisture stress occurs during a critical stage in crop development.

There is ample evidence that irrigation, if managed properly, can help you increase your yields substantially. In Mason County, research plots that were properly irrigated and fertilized yielded as much as 75 bushels of soybeans per acre in sandy soil. In Fayette County, yields of 60 bushels have been obtained on claypan soils that were adequately irrigated and drained. To obtain further information about irrigation development and each year's yields from research plots, subscribe to the *Illinois Irrigation Newsletter*, published by the University of Illinois, College of Agriculture. Subscription forms are available from your county Extension adviser. Your adviser can also give you application forms for membership in the Illinois Irrigation Association, which provides a subscription to the newsletter.

# List of Publications

The publications listed below contain additional information about soybean production. All publications are free except those for which a price is shown (these prices are subject to change), and all can be obtained from your county Extension adviser. The circulars and bulletins are also available from the Office of Agricultural Publications, 123 Mumford Hall, 1301 West Gregory Drive, University of Illinois, Urbana, Illinois 61801. To obtain items in the *Report on Plant Diseases* fact sheet series, you can write the Department of Plant Pathology, N-519 Turner Hall, 1102 South Goodwin Avenue, Urbana.

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**Double Cropping in Illinois.** Illinois Cooperative Extension Service Circular 1106. 31 pages.

**Drainage Guide for Illinois.** Illinois Cooperative Extension Service Circular (in preparation).

**Drying Grain in Illinois.** Illinois Cooperative Extension Service Circular 1100. 16 pages.

**Estimating Your Soil-Erosion Losses With the Universal Soil Loss Equation (USLE).** Illinois Cooperative Extension Service. 17 pages.

**Harvesting and Drying Soybeans.** Illinois Cooperative Extension Service Circular 1094. 12 pages.

**Illinois Agronomy Handbook.** Illinois Cooperative Extension Service Circular (revised biennially; the chapter entitled "Row Crop Weed Control Guide" is revised annually and published separately). 76 pages ($2.00).

**Illinois Soybean Disease Management Program.** University of Illinois Department of Plant Pathology Report on Plant Diseases No. 507. 10 pages (15¢).

**Insect Pest Management Guide: Field and Forage Crops.** Illinois Cooperative Extension Service Circular 899. 24 pages.

**Narrow-Row Soybeans: What to Consider.** Illinois Cooperative Extension Service Circular 1161. 7 pages.

**Performance of Commercial Soybeans in Illinois.** Illinois Cooperative Extension Service Circular (published annually).

**Soybean Diseases in Illinois.** Illinois Cooperative Extension Service Circular 1085. 31 pages.

**Soybean Insects: Identification and Management in Illinois.** Illinois Agricultural Experiment Station Bulletin 773. 64 pages ($4.00).

**Tillage Systems for Illinois.** Illinois Cooperative Extension Service Circular 1172. 24 pages.

**Weeds of the North Central States.** Illinois Agricultural Experiment Station Bulletin 772. 303 pages ($3.00).